

Rochester Institute of Technology

**RIT Scholar Works**

---

Theses

---

9-12-1991

## **A Pen-based computer for the delivery person**

Gwo-chyuan Chen

Follow this and additional works at: <https://scholarworks.rit.edu/theses>

---

### **Recommended Citation**

Chen, Gwo-chyuan, "A Pen-based computer for the delivery person" (1991). Thesis. Rochester Institute of Technology. Accessed from

This Thesis is brought to you for free and open access by RIT Scholar Works. It has been accepted for inclusion in Theses by an authorized administrator of RIT Scholar Works. For more information, please contact [ritscholarworks@rit.edu](mailto:ritscholarworks@rit.edu).

**ROCHESTER INSTITUTE OF TECHNOLOGY**

A Thesis Submitted to the Faculty of  
The College of Fine and Applied Arts  
in Candidacy for The Degree of  
**MASTER OF FINE ARTS**

**A Pen-based Computer for The Delivery Person**

**By**

**Gwo-chyuan Chen**

**September 12 , 1991**



## APPROVALS

Advisor: Professor Craig McArt

Date: 12/10/91

Associate Advisor: Douglas Cleminshaw

Date: 1991 Sep 18

Associate Advisor: James Sias

Date: 9/18/91

Special Assistant to the Dean for Graduate Affairs:

Professor Philip Bornarth

Date: 9/23/91

Acting Dean, College of Fine and Applied Arts:

Dr. Peter Giopulos

Date: 9/23/91

I, Gwo-chyuan Chen, hereby grant permission to the Wallace Memorial Library of RIT, to reproduce my thesis in whole or in part. Any reproduction will not be for commercial use or profit.

Date: 9/20/91

## TABLE OF CONTENTS

1.	INTRODUCTION	1
2.	DESIGN PROCESS	3
3.	RESEARCH	4
3-1	System Functions of Present Delivery Trades	4
3-2	Human Factors Consideration	6
	3-2.1 LCD Illumination	
	3-2.2 Hands Size	
	3-2.3 Control	
3-3	Environmental Consideration	9
3-4	Materials	10
3-5	Related Products Analysis	10
4.	TECHNICAL EXPLANATION OF PEN-BASED COMPUTER	12
4-1	Data Entry	12
4-2	Character Recognition	12
4-3	Display Screen	14
4-4	Data Storage	17
4-5	Power Supply	21
4-6	Ink-Jet Printer	22
5.	THE NEW TREND OF MICROELECTRONIC PRODUCTS DESIGN	25
5-1	From the Cube to the Plane	25
5-2	Agglomerative Design	26
5-3	Metaphor Design	27
6.	RESULTS OF RESEARCH	28
6-1	A New Concept to the Delivery Trades	28
6-2	Goals	30
6-3	Devices	31
7.	PRODUCT DEVELOPMENT	33
7-1	Design Direction	33
7-2	Concepts Initiation	34
7-3	Concepts Development	42
	7-3.1 Direction A: To Wear on the Wrist	
	7-3.2 Direction B: To Clip on the Belt	
7-4	Mock-up	49
	7-4.1 Mock-up A.	
	7-4.2 Mock-up B.	
7-5	Variation and Color Scheme	52
8.	THE RESULTS OF DESIGN	55
8-1	The Computer	58
8-2	The Carrying Case and the Printer	66
8-3	Colors	69
8-4	Exhibitions	70
9.	CONCLUSION	74
	BIBLIOGRAPHY	76

## TABLE OF ILLUSTRATIONS

Figure	page
1. The Design Process	3
2. The Principle of LCD Screen	16
3. The Flash Cell	20
4. The Principle of Bubble Ink Jet Printer	24
5. A New Concept for the Delivery Trades	29
6. Concept Sketch 1	34
7. Concept Sketch 2	35
8. Concept Sketch 3	35
9. Concept Sketch 4	36
10. Concept 1: Clipping on the Belt	37
11. Concept 2: The Calculator Size	38
12. Concept 3: The Geometric Shapes	39
13. Concept 4: Carrying by Handles	40
14. Concept 5: Carrying by Handles	41
15. Concept 6: Carrying by Handles	41
16. Wearing on the Wrist	43
17. Using a Universal Joint	44
18. The Space Station-like Form 1	45
19. The Space Station-like Form 2	46
20. Clipping on the Belt 1	48
21. Clipping on the Belt 2	48
22. Clipping on the Belt 3	49
23. Mock-up A	50
24. Mock-up B	51
25. Variation and Color Scheme 1	52
26. Variation and Color Scheme 2	53
27. Variation and Color Scheme 3	53
28. Variation and Color Scheme 4	54
29. The Full-Scale Final Model	56
30. The Way of Carrying.	57
31. Writing on the Screen by using a Light Pen.	58
32. Putting the computer into the Carrying Case.	59
33. Control Panel	60
34. The Light Pen	61
35. The Way to Take the Light Pen	61
36. The Disk Drives and the Central Unit Lock	62
37. The Way to Use The Disk Drive	63
38. The Way to Turn the Central Unit	64
39. The Battery Package	64
40. The Sculptural Handle	65
41. The Carrying Case and the Printer	66
42. The Printer	67

<b>Figure</b>	<b>Page</b>
43. The Way to Load the Paper Roll	68
44. Tearing the Printed Form	69
45. The Exhibition	70
46. The Story Board 1	71
47. The Story Board 2	72
48. The Story Board 3	73

<b>Chart</b>	<b>Page</b>
1. Morphological Matrix	33
2. Morphological Matrix-Direction A	42
3. Morphological Matrix-Direction B	47

<b>Table</b>	<b>Page</b>
1. Anthropometric Estimates for Hands	7
2. Push-button Dimensions	8

## 1. INTRODUCTION

A designer has the responsibility to utilize new technology to provide a solution for the people who need it. At the same time, the exploring of new technology to create an entirely new product is extraordinarily exciting.

In the beginning of the computer age, there was the keyboard. then came the mouse. In 1990, Grid Co. introduced the pen-based computer model.

The pen-based computer that lets users enter data or issue commands through a light pen writing on the screen is being developed. This is a new microelectronic technology. It uses a general computer, but without the keyboard.

The continuing advances in microcomputer technology have made possible a dramatic change in the ways computers are used, but much of the acceptance relies on how many developers come up with useful applications.

I wanted to take advantage of this new computer technology as a challenge for my thesis project. My goal was to design a housing and interface plan for a pen-based handheld computer to meet the particular needs of the delivery professional.

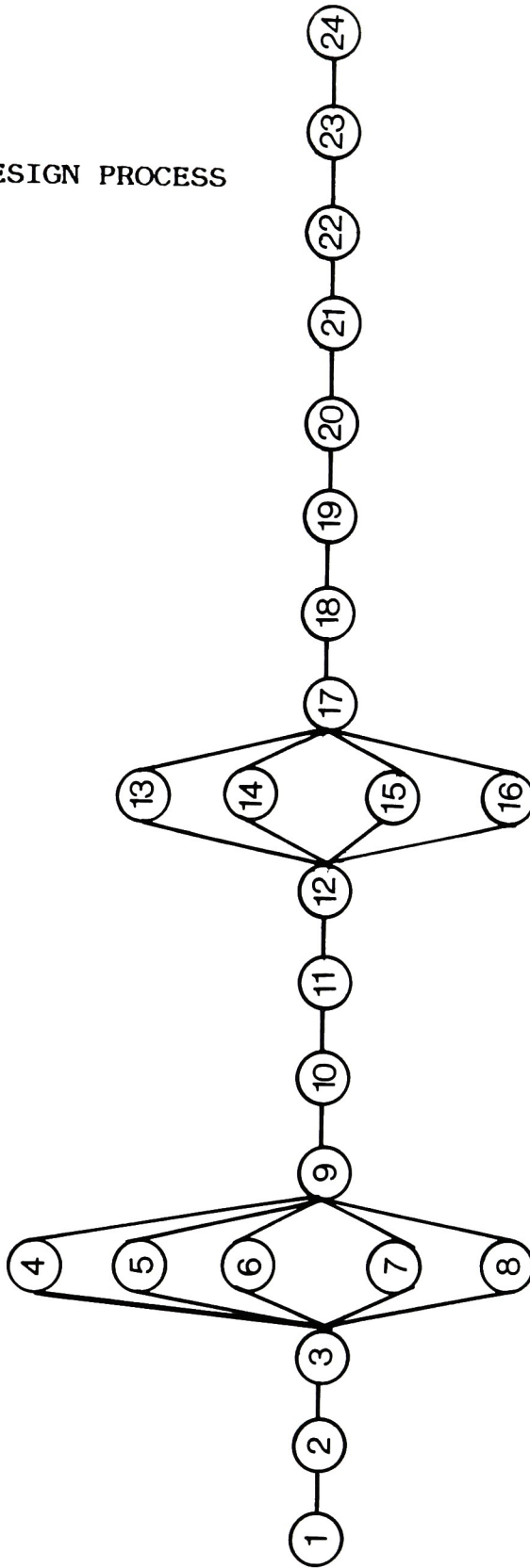
Two main aims were to be accomplished. They were: [1] to design a pen-based computer for delivery persons to help them work efficiently and easily; [2] to propose a new computerized concept to the delivery trades by using the pen-based computer.



This thesis will start with a research section. The research includes the functions of delivery trades, human factors, environments, materials, related products, and technical investigation.

The following section will be the design process that I used to create the new pen-based computer. It will cover the goals, the criteria, the process of development and the results of the design. It will propose a new concept to the delivery trades as well.

## 2. DESIGN PROCESS



- |                             |                          |
|-----------------------------|--------------------------|
| 1. Pre-marketing            | 13. Design Direction     |
| 2. Finding The Topic        | 14. Concepts Initiation  |
| 3. Research and Analysys    | 15. Concepts Development |
| 4. Needs of users           | 16. Concept Refinement   |
| 5. Human Factors            | 17. Mock-up              |
| 6. Environment              | 18. Final Design         |
| 7. Materials                | 19. Technical Drawing    |
| 8. Related Products         | 20. Color Scheme         |
| 9. Problem Definition       | 21. Design Examination   |
| 10. Exploring Possibilities | 22. Design Refinement    |
| 11. Design Goals            | 23. Final Mock-up        |
| 12. Design Development      | 24. Exhibitions          |

Figure 1. Design Process

### 3. RESEARCH

The project started with research and analysis. The scope of the industrial designer's task is comprehensive. It is impossible for designers to be familiar with every product's design. The functions of research and analysis in product design are such that [1] Designers will get a good understanding of the products which are being worked on, [2] Designers will, based on the existing products, develop new concepts and avoid the same mistakes which have been made before, [3] Designers will find the problems of existing products and give them solutions.

#### 3-1 System Functions of Present Delivery Trades

Basically, the function of delivery trades is forwarding parcels which the shipper consigns to the destination. However, the process of taking customers' orders and sending the parcels to their destination is really complicated.

When sending their parcels to the delivery company, shippers have to fill out shipping forms. The representative of the delivery company checks the packages' contents and amounts, and duplicates the destination address on each package. Then, these packages are sent to warehouses for storage and sorting. Workers in the warehouse group the packages by the location of the destination or by the priorities.



Delivery persons pick up groups of packages and receipts from the warehouse. First, they have to arrange the routes according to the destination. After that, The delivery person delivers the packages to each destination according to the sequence in which they are arranged.

When receivers get packages, they sign the receipts as evidence of receiving them. If the receiver is not in, the driver has to fill out another form. The driver gives a customer copy to the receiver, and keeps the company copy as a shipping record.

After finishing all the delivery procedures, the driver goes back to the company and returns the receipts to the staff. The company staff keeps the receipts as proof that the delivery company has sent the packages to the receivers. Usually, the delivery company saves the receipts for 3-5 years in case of any argument between customers and company. To do this, the company needs a huge, safe space to store receipts.

There is a lot of paper work during the shipping and receiving process. How to keep documents safe and how to keep the numbers low is always a problem for the delivery trades. Recently, more and more companies have used computers to manage, and it really simplifies the shipping and receiving procedure. However, the problems still exist. The companies simply have to find a place to store customers' signed

receipts, because there is no way to save customers' original signatures on computers.

Since 1991, UPS (United Parcel Service) has begun using electronic script boards so that customers sign on this board directly, and this signature can be saved on the computer as a record. This is a step forward toward computerizing the delivery trades .

### 3-2 Human Factors Consideration

#### 3-2.1 LCD (Liquid Crystal Display) Illumination

Plain LCD screens are difficult to read in dim light. To be readable at all, there needs to be sufficient light in the room.

They do little better if the light source hits the screen at the wrong angle or any angle that is not over the shoulder. And even when a screen is illuminated, the viewer needs to sit directly in front of it viewing at a perfect right angle to the surface. The more off-axis one view his or her image, the more unreadable it becomes. "At 20 degrees off-axis, text and background become indistinguishable on some models. Others LCD will permit viewing angles ranging from 30 to 40 degrees off-center. But few go beyond 60 degrees, horizontally or vertically."<sup>1</sup>

---

1. Sanders, Mark S. and McCormick, Ernest J.. Human Factors in Engineering and Design, Sixth edition, p.389, McGraw-Hill, New York, 1987.

### 3-2.2 Hand Size

In hand-held computer design, important human factors problems which relate to the hand are present. The product's dimensions and the manner of using it depends on the ergonomics of hands.

Anthropometric data for hands may be applied in this design.

Dimension	Man				Woman			
	Percentiles				Percentiles			
	5th	50th	95th	SD	5th	50th	95th	SD
1. Hand Length	173	189	205	10	159	174	189	9
2. Palm Length	98	107	116	6	89	97	105	5
3. Thumb Length	44	51	58	4	40	47	53	4
4. Index Finger Length	64	72	79	5	60	67	74	4
5. Middle finger Length	76	83	90	5	69	77	84	5
6. Ring Finger Length	65	72	80	4	59	66	73	4
7. Little Finger Length	48	55	63	4	43	50	57	4
8. Thumb Breadth	20	23	26	2	17	19	21	2
9. Thumb Thickness	19	22	24	2	15	18	20	2
10. Index finger Breadth	19	21	23	1	16	18	20	2
11. Index finger Thi.	17	19	21	1	14	16	18	1
12. Hand Breadth	97	105	114	5	84	92	99	5
13. Palm Breadth	71	81	85	6	63	71	79	5
14. hand Thickness	44	51	58	4	40	45	50	3
15. Max. Grip Diameter	45	52	59	4	43	48	53	3
16. Max. Spread	178	206	234	17	165	190	215	15
17. Functional Spread	122	142	162	12	109	127	145	11

NOTE:

1. All dimensions are in millimeters.
2. Thi.- Thickness.
3. SD- Standard Deviation

Table 1. Anthropometric Estimates for Hands

Source: Pheasant, Stephen, Bodyspace, p. 126, Taylor & Francis, London, 1986.

### 3-2.3 Control

A push-button of the computer should have a positive snap-action which gives tactile feedback and, preferably, an auditory click. For enhanced feedback, an associated indicator or light is helpful. A high friction or dished surface aids finger control. The surface of the push-button should be made matte to prevent annoying reflection.

The dimensional considerations of fingertip operation of push-button controls are shown in table 2.

	Minimum	Preferred	Maximum
<b>Fingertip Operation</b>			
Edge length	6	12-15	25
Travel	3	5-10	35
Resistance	0.15	0.25-0.35	1
<b>Separation</b>			
Single Finger(random)	15	50	—
single Finger(sequential)	6	25	—
Several Fingers	—	100-150	—

**NOTE:**

All dimensions are given in millimeters and resistances in kilogram force.

Table 2. Push-button Dimensions

Source: Pheasant, Stephen, Bodyspace, p. 236, Taylor & Francis, London, 1986.



### 3-3 Environmental Consideration

Delivery persons are the on-the-road workers. Their working environments are varied. No matter whether it is sunny or rainy or summer or winter, they always work outdoors. Product design for these people must take into consideration the change of surroundings to protect the computer from damage.

Temperature and humidity for outdoor work vary. Computers for outdoor should be designed to operate between -20 and 60 degrees C. This can be accomplished by the use of certain materials or by designed devices which keep the computer within appropriate temperature and humidity ranges.

Moisture and dust also cause problems in computers. The delivery person cannot stop working during rainy days, so computers can get wet. The computer needs to be water resistant.

The working style of delivery persons involves continual movement. Their work includes driving trucks, moving parcels in and out, and getting in and off trucks. In these serial activities, hand-held computers can be hit, dropped and vibrated. How to protect computers from damage should be emphasized.

Pen-based computers usually are powered by batteries. They consume large quantities of power in order to perform well and avoid losing important data. Rechargeable batteries are good for this type of computer. They should take a short time to recharge and have a long life between recharging.

### 3-4 Material

PC (Polycarbonate) will be used as the plastic molded shell. "PC is a high performance, amorphous engineering thermoplastic that is characterized by high clarity, heat-and flame-resistance, dimensional stability, and exceptionally high impact strength over a wide temperature range."<sup>2</sup>

"A large application market is in the electronics and business equipment fields."<sup>3</sup>

### 3-5 Related Products Analysis

This pen-based computer is created for certain needs of the delivery person, and it is designed for specific functions.

---

<sup>2</sup> Mehta, Kishor S., "Polycarbonate", Modern Plastics Encyclopedia '89, Mid-October Issue, pp.38, 40, Plastics Catalogue Corp., 1989.

<sup>3</sup> Ibid.

UPS's electronic script boards are the only similar products available on the market so far. They can record the customer's signature, but they cannot offer the proper information such as the customer's address, amount of parcels, etc. to the delivery person.

The UPS script board does not have a printer on the road. It still needs to go back to paper work for the communication between customers and the delivery company.

The size of the Electronic script board is similar to a note pad (9"x 12"), and it weighs 4 lbs.

The electronic script board is carried by hands. The delivery person often must use two hands to move the parcels. In so doing, one must put the script board on the top of parcels or sandwich it between parcels. Under these circumstances, the boards are often dropped.

The display screen is on the top of the electronic script board, and below the screen is the keyboard. When writing on the UPS electronic script board, the user must put his or her hand on the keyboard. Even though this movement does not cause damage to the script board, the layout of screen and keyboard is still bothersome to the user.

## 4. TECHNICAL EXPLANATION OF THE PEN-BASED COMPUTER

### 4-1 Data Entry

In the pen-based computer, data input is registered when the stylus (the electronic light-pen) makes a circuit via an electrically conductive film over the LCD screen. The electrically conductive film is known as the "transparent tablet"<sup>4</sup>. Rather than reading out locations from a grid of wires, the digitizer measures resistance across a conductive layer deposited on glass, producing a totally transparent digitizing surface.

"As the stylus moves, electromagnetic sensors around the screen measure its location, sending signals to the computer, which then draws the shape on the screen. This capability is analogous to working with pen and paper in two respects: the writing area and display are, at least approximately, the same surface, and the displayed trace of the stylus gives the user immediate feedback of captured writing."<sup>5</sup>

### 4-2 Character Recognition

Text is usually represented in computer systems by a coding system called ASCII code, which represents each character by an 8-bit code. This is a very economical way of representing characters in terms of storage and permits computer manipulation of the code. The graphic image of a text character typically takes about 100 times as much space as an

---

<sup>4</sup> Free, John, "Electronic Newsfront", Popular Science, p.37, June 1991.

<sup>5</sup> Ibid.



ASCII character. A technique does exist which converts character images to ASCII character. It is known as optical character recognition (OCR)

Basically, the procedure of OCR is a series of comparisons. "The process includes three steps which are contour tracing, feature extraction and classification."<sup>6</sup>

"While going around the contour of a shape, the algorithm cuts the curve into significant parts. The ending points, the curvature, and the convexity-concavity of these parts will be coded as the extracted features of the contour. There are two main codes generated: the shape code and the position code."<sup>7</sup>

The shape code contains the information as to whether a part of the contour is convex or concave. The normalized position of the ending points is accumulated in the position code.

The extracted features mentioned characterize the shape of a letter. For correct recognition of a letter, additional information is needed. "We have to use the actual size of letters to distinguish between the low and upper case from the same letter pairs (c,C,s,S,p,P...)." <sup>8</sup>

"On the first level of classification, the software finds a route in the tree, a structure which enables fast classification to be done, using the shape code and the loop code (describing the inner contour and their relative position). At the end of this branch, letters having similar

---

<sup>6</sup> Marosi, I. and Kovacs, E., "Developing a General Purpose Optical Character Recognition System", Imaging Workstations and Document Input System, SPIE Vol. 1074, pp.180, 1989.

<sup>7</sup> Ibid., p.181.

<sup>8</sup> Ibid.

shapes are found. Using the position code, the computer searches for the best matches in this set of characters. The most likely character code is selected according to the position, size, and text environment of the shape."<sup>9</sup>

Because handwriting characters are more difficult to recognize than print characters are, the user sometimes has to train the computer to recognize a distinctive writing style. To train the machine to recognize a particular style of writing, users jot down a few sample sentences that use every letter in the alphabet. Once the machine has studied and recognized the individual user's handwriting, the user's profile is stored.

#### 4-3 Display Screen

Most desktop computers use cathode ray tube (CRT) displays. But because these glass tubes are bulky, weighty, fragile, and require a large quantity of power, they have proved to be totally impractical for the road. Three practical techniques are suitable for laptop, notebook or hand-held computer so far. They are Liquid Crystal Displays (LCD), Electroluminescent displays (EL) and Gas Plasma displays. Each type has its own advantages and disadvantages.

Like the CRT displays, Gas Plasma displays give off their own light, and have as many pixels as many CRTs. Gas Plasma Displays can offer a bright, clear, sharp image, and don't have the viewing angles ranging problem like LCD screens have.

---

<sup>9</sup> Ibid.

Gas plasma displays' chief disadvantage is the enormous amounts of power required. Few batteries can drive them for long. In addition to power consumption, another drawback of Gas Plasma Displays is the limited amount of shading possible.

EL displays are small in size and light in weight, and their picture resolution is good. However, power consumption is too great for a portable application.

LCDs are lightweight, thin and durable screens for the road. At the same time, they are relatively inexpensive to produce and don't consume much power. There are now several portable computers with LCD screens that will run for hours on simple AA batteries. LCD screens are now popular screens for portable computers.

"LCDs operate by means of two sets of electrodes: a transparent metallic electrode on the front panel and a corresponding set of rear electrodes. Between these two sets of electrodes is a special, gooey liquid known as liquid crystal. This gooey liquid has within it tiny crystals that are sensitive to tiny electrical charges. When an electrical current is passed through the liquid, these crystals also bend the incoming light rays in two different directions, thereby dividing the light into two discernible rays. This phenomenon is known as birefringence"<sup>10</sup> (See figure 2).

"To take advantage of the birefringent properties of the liquid crystal and produce an image on the screen, the front screen is coated with a polarizing material. Because light

---

<sup>10</sup> Sherr, Sol, Output Device, p.216, Academic Press, New York, 1988.



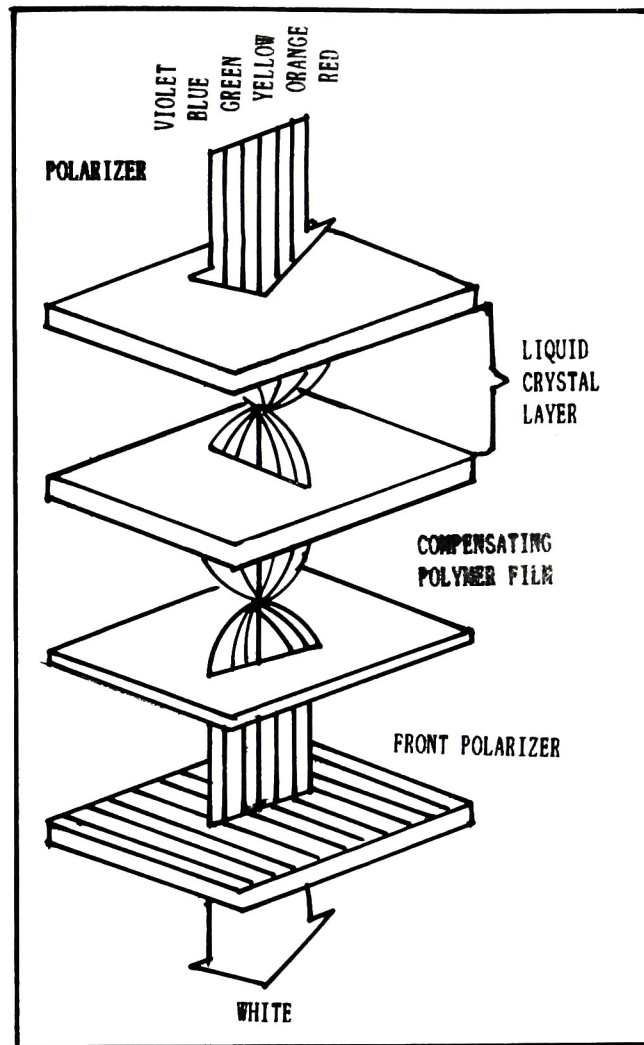


Figure 2. Principle of LCD Screen

Source: Lieberman, David, "A New LCD Structure", Computer Design, p.37, April, 1989.

waves vibrate both horizontally and vertically, producing bright reflections of shiny surfaces, polarizers are used to cut down the glare by blocking out all the light waves on the vertical plane. The more voltage that is applied to the liquid crystals, the more they will twist and bend the phase of the rays of light passing through them. When the light rays' angle has shifted to the point where the polarizer blocks out the

light, a dark area appears on that spot of the screen. Varying the voltage also varies the degree of darkness, making shading and limited contrast possible."<sup>11</sup> The total image is formed on the LCD panel in much the same manner as that of a CRT screen. It is scanned from left to right and top to bottom.

The main drawback of the LCD is its low contrast, which can be difficult on the eyes, and this can slow down the on-screen reading speed.

The viewing angle is the other weakness of an LCD. An LCD has only a small range of an optimum viewing angles, and resolution at other angles is poor.

LCD screens are susceptible to heat. Leaving them in a hot truck or exposed to the summer sun for a long period can darken the image considerably.

#### 4-4 Data Storage

Computers are increasingly used on the road. "...these devices have a few weak spots when it comes to working in a harsh environment. One of those spots is the disk drive. The rotating platters of conventional drives with 'flying heads' are susceptible to shock, vibration, and temperature variations. As more equipment becomes dependent on computer control, ways must be found to protect the drive, work around it, or work without it."<sup>12</sup>

---

<sup>11</sup> Ibid.

<sup>12</sup> Cooper, Steve, "A Rugged Alternative to Computer Disks," Automation, p.30, April, 1990.

There are some alternatives to conventional disk drives, but each has peculiarities that limit its application. There are CMOS (Complementary Metallic Oxide Semiconductor) RAM (Random Access Memory), Disk-less, EPROM (Erasable Programmable Read Only Memory) and Flash Solid State Disk.

CMOS RAM, using battery support, provides high performance read/write capabilities, but is expensive and space consuming, so it is typically limited to a small amount of storage capability.

"Disk-less" is a local area network to a remote file server. This approach lets the computer access hard disks as if they were local, but it requires the presence of a remote file server, and makes the system dependent on its and the network's, operation.

Some computer systems do without a disk drive, operating instead from EPROM chips for program storage. This approach works for dedicated control algorithms, but can not easily accommodate program changes or permanent storage of changing system parameters essential for statistical process control. "EPROMs require exposure to ultraviolet light for 10 to 20 minutes."<sup>13</sup>

Flash Solid State Disk, sized in 63 mm x 52 mm x 6 mm, can be configured to operate as a rugged, solid-state disk drive and can replace traditional hard disk drives in computers. Flash memory disk drives have no moving parts, and are rugged.

---

<sup>13</sup> Ibid., p.31.

"Flash memory solid-state disks have a new set of advantages and capabilities. These disks are readable, like conventional hard disks, so that software can be used unchanged. Flash-memory disks are also easily erased and reprogrammed."<sup>14</sup> "Current chip densities allow solid-state disk drives up to 6 Mbytes in capacity."<sup>15</sup>

The flash chips can be erased electrically. They use a technology known as Hot Electron Injection. "A high voltage (+12 v) is applied on gate and drain while the source is grounded. This causes electrons to move to the floating gate, where they are trapped"<sup>16</sup> (see figure 3).

There are two unique properties to consider when using Flash-based disks, both related to a writing device. "The first is that individual locations of the flash chips cannot be directly written on. Thus, to change the contents of the flash disk, one must erase the entire disk and then reload its entire contents."<sup>17</sup> It cannot be used as a standard read/write disk. "For applications that need full read/write capability the user can set up a RAM disk for rapid read/write capability, and have the RAM disk contents intermittently loaded onto the flash disk for storage."<sup>18</sup>

The second unique aspect of flash disks is the limit of reliable erasures. Current chips allow a maximum number of 10,000 erasures; therefore, solid-state disk designs must

---

<sup>14</sup> Ibid., p.30.

<sup>15</sup> Ibid.

<sup>16</sup> Ibid.

<sup>17</sup> Ibid.

<sup>18</sup> Ibid.



count the number of times the disk has been erased, and offer warnings when the limit is approaching the maximum.

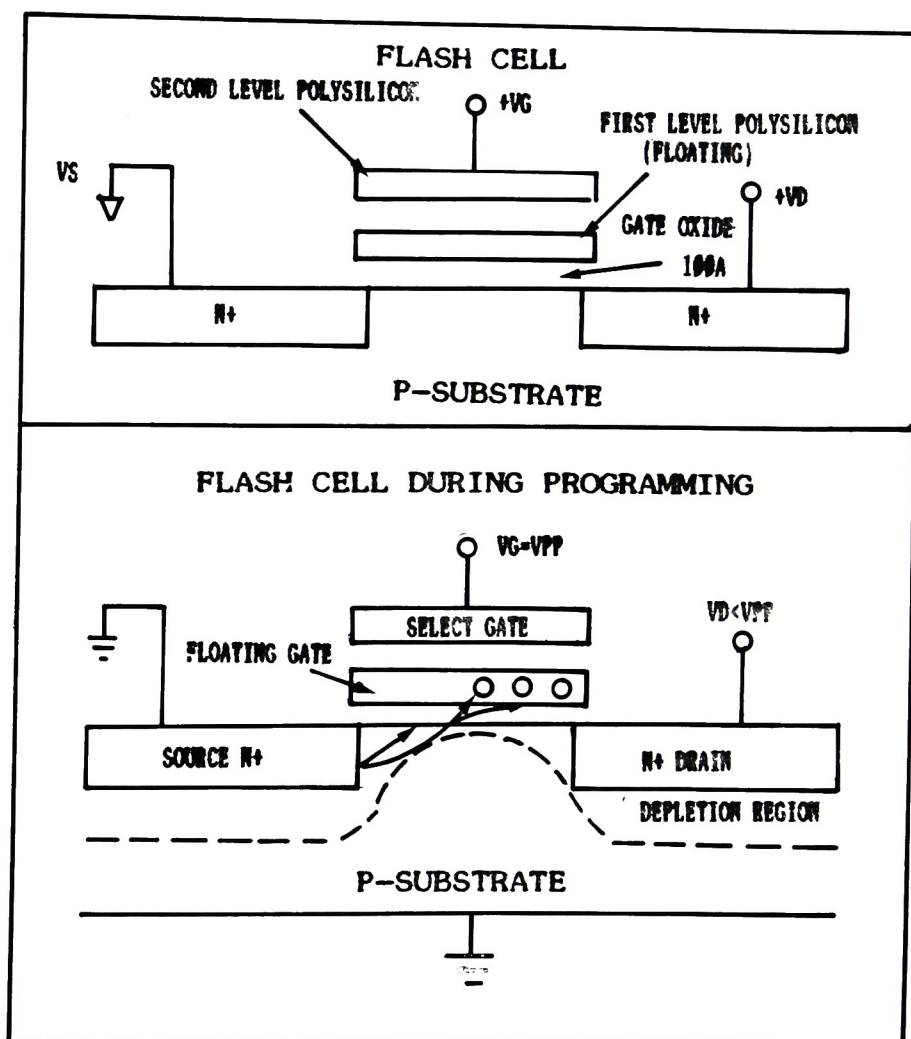


Figure 3. The Flash Cell

Source: Cooper, Steve, "A Rugged Alternative to Computer Disks," Automation, p.31, April, 1990.



#### 4-5 Power Supply

Except for certain large portable computers with gas plasma displays, almost all portables are run on batteries, and rechargeable batteries come with most of them. Here, one must consider not only how long the batteries run, but also how long it takes for them to recharge.

The five main types of batteries now on the market are zinc chloride, lead-acid, gel-cell, alkaline and nickel-cadmium. Each of these types has its own set of sizes, shapes, configurations and ratings.

Zinc chloride batteries are generally found in the notebook style and pocket computers. They can be recharged about three or four times, and come in sizes AAA, AA, A, C and D.

Lead-Acid batteries are found in everyone's car. They are eminently rechargeable and have a long life between charging. Typically, lead-acid batteries work well with portable computers.

The chief drawback of lead-acid batteries is the cost. They are also on the expensive side and are not always easy to locate. The lead-acid batteries also are very heavy for power available and have the danger of acid leak.

The Gel Cells would be an excellent choice for laptops because they can deliver plenty of current over sufficient periods of time. The reason why we are not likely to find them packed in with our laptops is their excessive weight.

Alkaline batteries have the shape and size of zinc chloride batteries. They last anywhere from three to eight times as long as zinc chloride batteries, and they are only about twice the price. The chief disadvantage of alkaline batteries is that they cannot be recharged.

Nickel-cadmiums are by far the most popular of rechargeable batteries. They work well with most lightweight portables and are relatively inexpensive. NiCads can be recharged quickly, easily and often. Heavy-duty laptop computer users can make good use of NiCads by using ready-to-go power packs.

#### 4-6 Ink Jet Printer

The general idea of the "ink jet" is that "they take small quantities of ink from a reservoir, convert them into drops, and transport the drops through the air to the printed medium by an appropriate application of physical forces."<sup>19</sup>

There are two major classifications of ink jet. In "continuous"<sup>20</sup>, drops are formed at high rates even when there is no printing and are selected and guided to the printing medium by electrostatic or magnetic forces. The other one is "drop-on-demand"<sup>21</sup> (DOD), in which drops are formed only when required. These are not jetting devices. The forces used to create and transport these drops may be mechanical, electrolytic, magnetic, or thermal.

---

<sup>19</sup> Durbeck, Robert C. and Sherr, Sol, Output Hardcopy Device, p.311, Academic Press, Boston, 1988.

<sup>20</sup> Ibid.

<sup>21</sup> Ibid.

In continuous ink jet, "only a small fraction of the drops are used for printing, the majority being directed to a catch gutter and recirculated via a pump and filters."<sup>22</sup> This recirculation tends to make continuous ink jet printers more expensive and larger than DOD printers. Thus, most compact jet ink printers are using the drop-on-demand theory.

In a recent DOD ink jet technology, thermal-bubble ink jet, heating of a thin film resistor causes sudden vaporization of a small portion of the ink vehicle; this displaces fluid in the ink chamber causing drop ejection (see figure 4). The resistor is comparable in size to the orifice diameter; thus, high density packaging of printing elements is possible. The reason why I chose this thermal-bubble ink jet print in my design is not only its high printing quality, but also its small volume and inexpensive cost.

---

<sup>22</sup> Ibid., p.323.

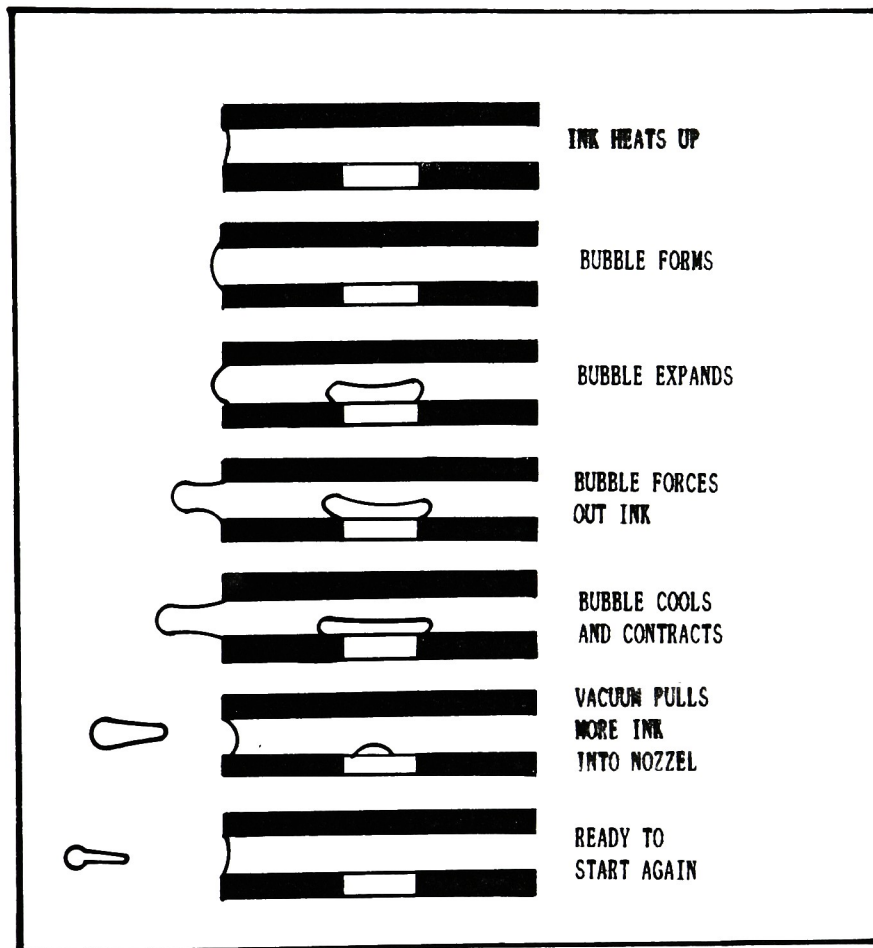


Figure 4. Principle of Bubble Ink Jet Printer

Source: Durbeck, Robert C. and Sherr, Sol, Output Hardcopy Device, p.320, Academic Press, Boston, 1988.

## 5. THE NEW TREND OF MICROELECTRONIC PRODUCT DESIGN

From functionalism, post-modernism to present new design approaches, "not only the theoretical approach but also the motives of the design debate have changed considerably over the last ten years."<sup>23</sup> Because of the changing of life-styles and influence of high-tech technology on design, functionalism is not the only valid concept of design.

Microelectronics seems to be so far-reaching that it is certain to lead to revolutionary changes in our way of life and work. The technological revolution, especially in the field of microelectronics, means that we must give refreshed consideration to the inquiry of design. Any form of stylistic evolution in design will therefore have to take new technology into account.

### 5-1 From the Cube to the Plane

"The increasing loss of the third dimension is one of the most obvious effects of electronic miniaturization on design"<sup>24</sup>, so far. This is not just an objective parameter of external dimensions: "design has appropriated the phenomenon as a cipher, so that 'flat' has come to signify advanced, high-quality, or simply electronic".<sup>25</sup> Designers attempt to

---

<sup>23</sup> Gros, Jochen, "Small But Sophisticated", Design Now Industrial or Art, p. 266. Prestel, Munich, 1989.

<sup>24</sup> Ibid., p.266.

<sup>25</sup> Ibid., p.267.



make what volume is left at least appear to be two-dimensional.

"Thanks to electronics, The 'Ulm cube', one of the major form ideals of functionalism, has lost its validity... Thus the plane, as the principal cypher of the 'new technology', takes on more and more the role of a proto-form."<sup>26</sup>

Even mechanical artifacts are looking flatter and flatter, just as in its day the streamline style was appropriated for objects which had no need to reduce wind resistance.

## 5-2 Agglomerative Design

"Quality design has always tried to represent something of the essence of the product or of its technology."<sup>27</sup> Why is it that a fundamentally agglomerative technology like electronics is still in many cases housed, or rather hidden, in a classically integrative casing? "For such an 'additive' technology it would be much more appropriate to design an additive housing."<sup>28</sup>

This inside is now being reflected in a growing number of design. "Thus, 'Two Super-cyphers' can be identified in the

---

26 Ibid., p.267.

27 Ibid., p.268.

28 Ibid.

product language of electronics: flatness, which refers to the trend towards 'dematerialization', and agglomerative design as a symbol of the new, similarly characterized technology."<sup>29</sup>

The agglomerative concept of design is "breaking the box". It is gaining not only in electronics. Even some mechanical equipment is nowadays designed as an agglomeration of separate parts.

### 5-3 Metaphor Design

"The 'good design' no longer must be fashioned 'from inside to outside', or the 'honest' design does not have to externally reflect the functional essence of a product. On the contrary, the internal anonymity of microelectronics engenders more and more attempts to seek external explanation."<sup>30</sup>

" 'Metaphor design' has become the most important trend of recent years."<sup>31</sup> The form is as a screen onto which metaphorical interpretations of invisible technology can be projected. The designer must have something to say about this faceless technology in the form of product-language, or the user will do it his own way.<sup>32</sup>

---

29 Ibid., p.268.

30 Ibid., p.269.

31 Ibid.

32 Dormer, Peter, The Meaning of Modern Design, pp.170-181, Thames and Hudson, New York, NY, 1990.

## 6. RESULTS OF RESEARCH

### 6-1 A New Concept for the Delivery Trades

Because of the benefits of the new computer technologies, here a new concept is proposed for the delivery trades. The pen-based computer plays an important role in this new concept. It solves the problem of how to save documents safely and how to keep the numbers of papers low. It offers more detailed information to the delivery person as well.

In the new computerized delivery process (see Figure 5), when sending parcels via a delivery company, the sender (customer) fills out a shipping form which is shown on the pen-based computer screen. This hand written information will be recognized and converted to text type, except for the signature, by OCR software. The delivery company representative gains all the information from a computer network so that he or she can check the parcels and information to see that all is correct. The main computer also sorts the packages and gives a designated area code according to the receiver's address or priority. The delivery company staff prints out the propriety information and attaches it to each package.

The delivery person obtains a data disk which loads groups of packages and receiver information from the staff. After putting this disk into his or her pen-based computer,



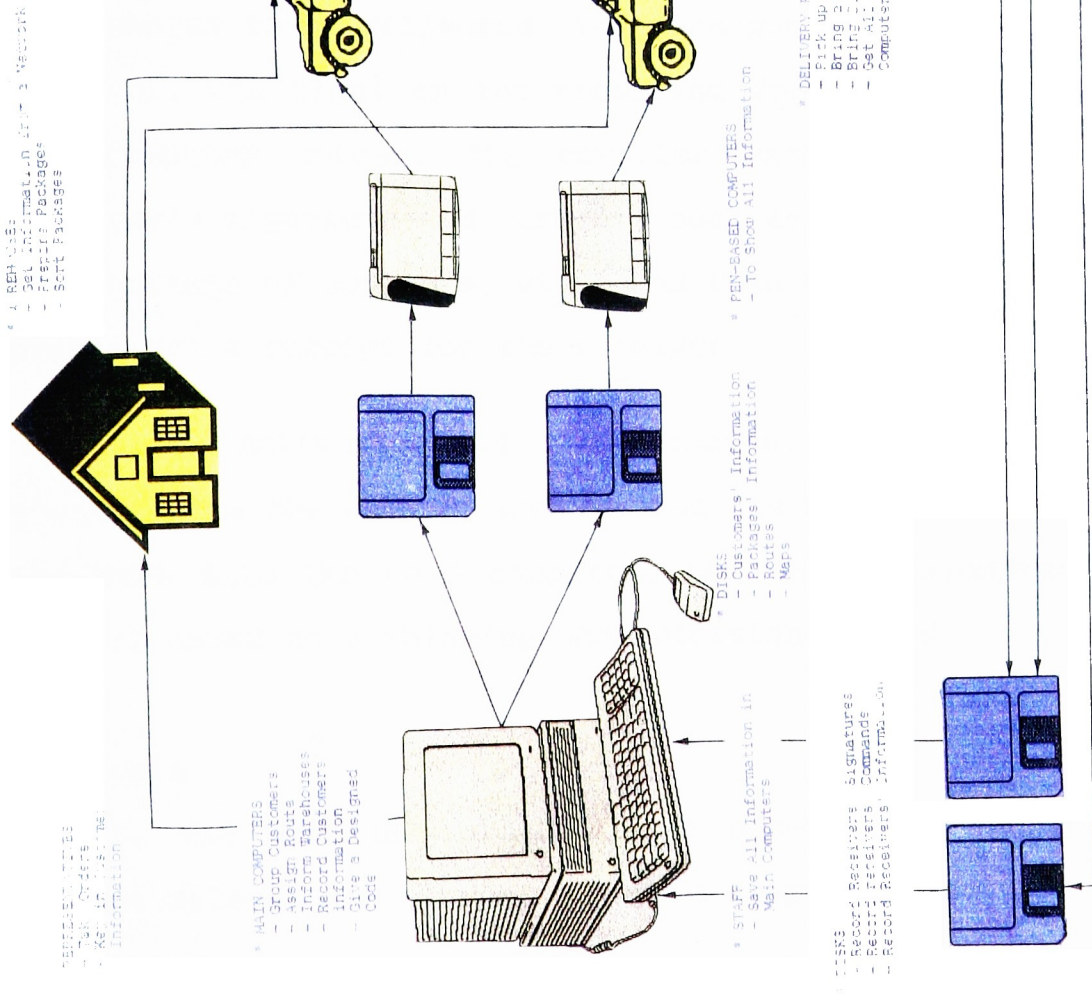


Figure 5. A New Concept for the Delivery Trades

the delivery person can get information not only about the packages and receivers but also about the map, route and other things.

According to the information which is shown on the computer, the delivery person goes to the warehouse and picks up packages to be delivered. The packages are delivered to the receiver, who signs on the receiving form, which is shown on the computer screen. The computer makes a record of the receiver's signature and comments such as damages of packages, the shortage of contents, etc., and then the accessory printer prints out a receipt for the receiver.

After delivering all the packages, the delivery person goes back to the company and returns the disk. The staff place the disk into the main computer, and the information in the disk is saved as a shipping and receiving record.

## 6-2 Goals

1. The Unit should combine a pen-based computer, data storage devices and a printer into a compact product.

2. The pen-based, hand-held computer should be of small size, lightweight, and easy to carry without using both hands.

3. It should be capable of presenting the text and the graphic mode.

4. It should have an interface or a connector to link with the main computers.

5. It should accommodate both right-handed and left-handed users.

6. The power supply should not restrict use to a certain location or short amounts of time.

7. It should be designed to avoid dropping.

8. The computer should be designed for water, dust and shock resistance.

9. It should be easy to get information when delivery person are driving vehicles.

10 . It should be easy to be used when there is no working surface to rest it on.

11. The mapping of control panel should be simplified in order not to be confusing to the user.

12. The form should reflect new trends in design.

### 6-3 Devices

This pen-based, hand-held computer should include:

1. a hand-writing screen computer,
2. a light pen and a pen holder,
3. a printer,

4. two data storage devices which use flash solid state disks,

5. a power supply which use a 12 v rechargeable NiCad battery package,

6. carrying devices and

7. connectors.

## 7. PRODUCT DEVELOPMENT

### 7-1 Design Direction

In the beginning, the goals were divided into individual small units. Then, I found several different answers for each unit and I put them into a matrix which is called the "Morphological Matrix"<sup>33</sup>. ( see chart 1)

Goals	Possible Solution to Goals			
Carrying	Bag/case	Clip on belt	Pocket	fix on body
Resistance	Seal off	Bag	Cover	
Avoid to Dropping	Texture/Form	Belt/wire	insurance devices	fix on body
Working Surface	Table	Palm	Arm	Body
Suit for Right/Left Hand Users	Form	Detach-able	Turnable	
Light-pen storage	Build in	Pocket	Case	
Printer and System	Separate	Build in		

Chart 1. Morphological Matrix

When I designed this project, I chose different solution combinations from the Morphological Matrix. This systematic design method assisted me to focus on certain goals and to give a thorough consideration to design.

<sup>33</sup> Crawford, C. Merle, New Products Management, Second Edition, p.155, Irwin, Homewood, IL, 1987.





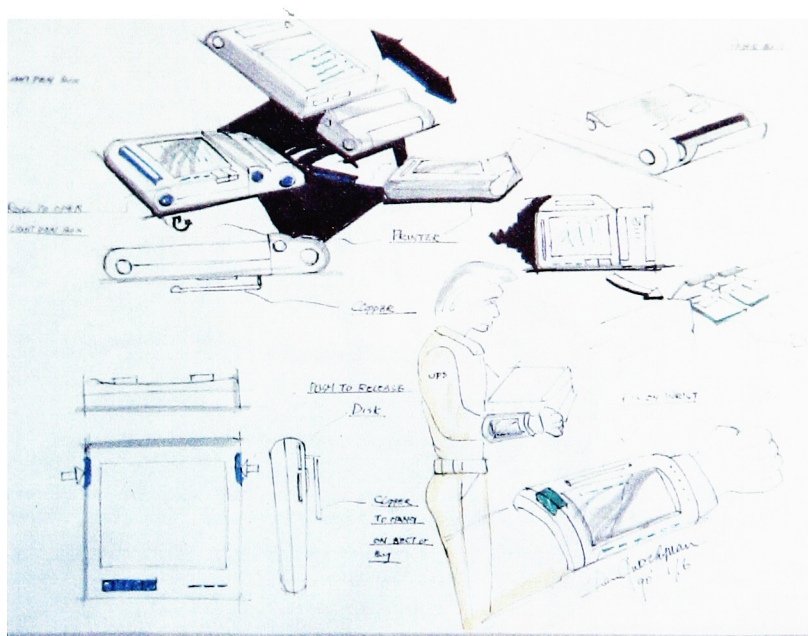


Figure 7. Concept Sketch 2

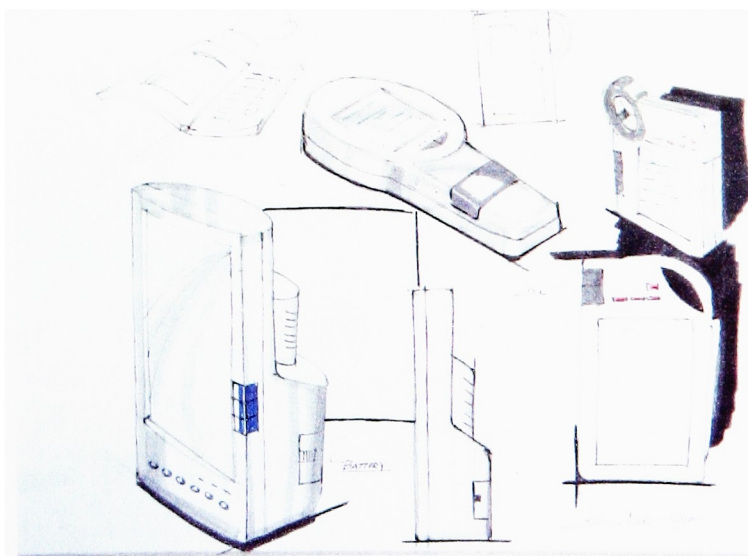


Figure 8. Concept Sketch 3

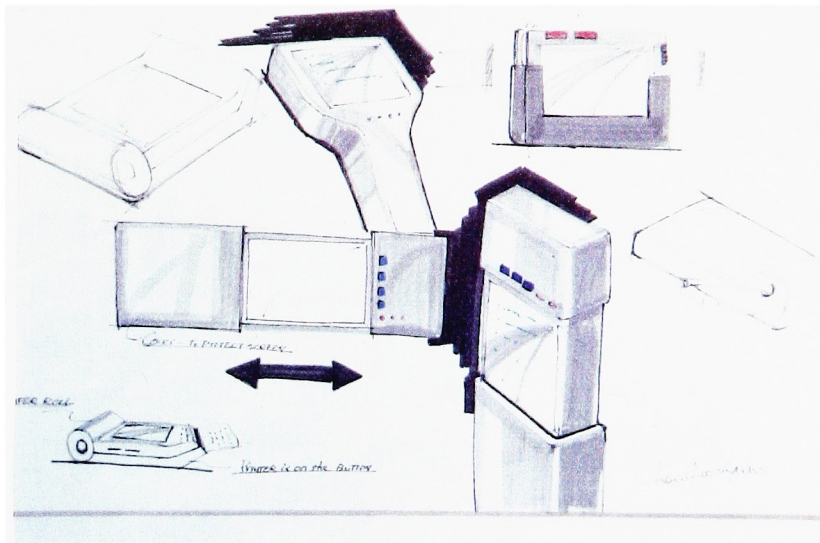


Figure 9. Concept Sketch 4

Figure 10 is an idea which uses clips to hang on the belt. It combines a computer, a printer, a stylus and a battery package, and uses a cover to protect the screen from damage.

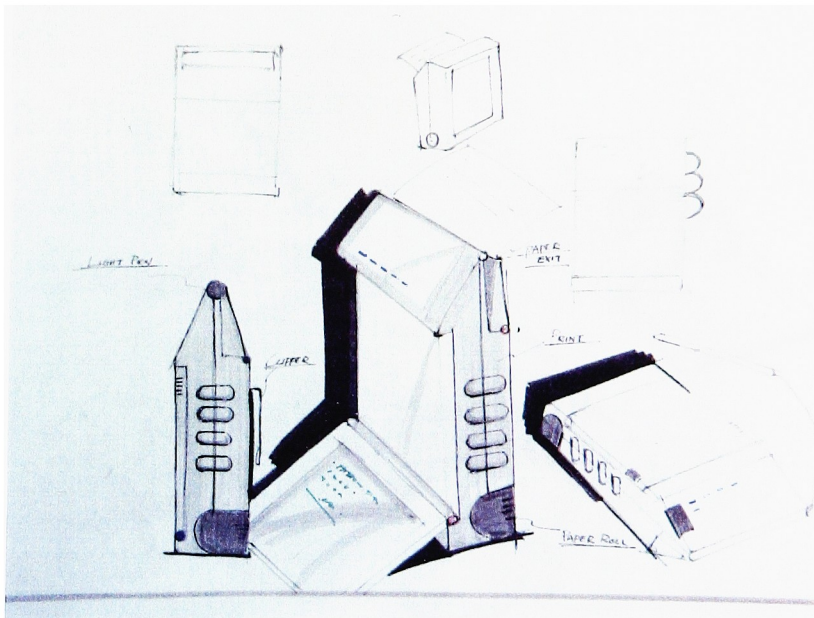


Figure 10. Concept 1: Clipping on the Belt



Figure 11 explores the small size of the computer, which is similar to palm-sized calculators. They are designed small in size to put in the pocket or to wear on the wrist; however, for computers, they are too small to read and to place information in.

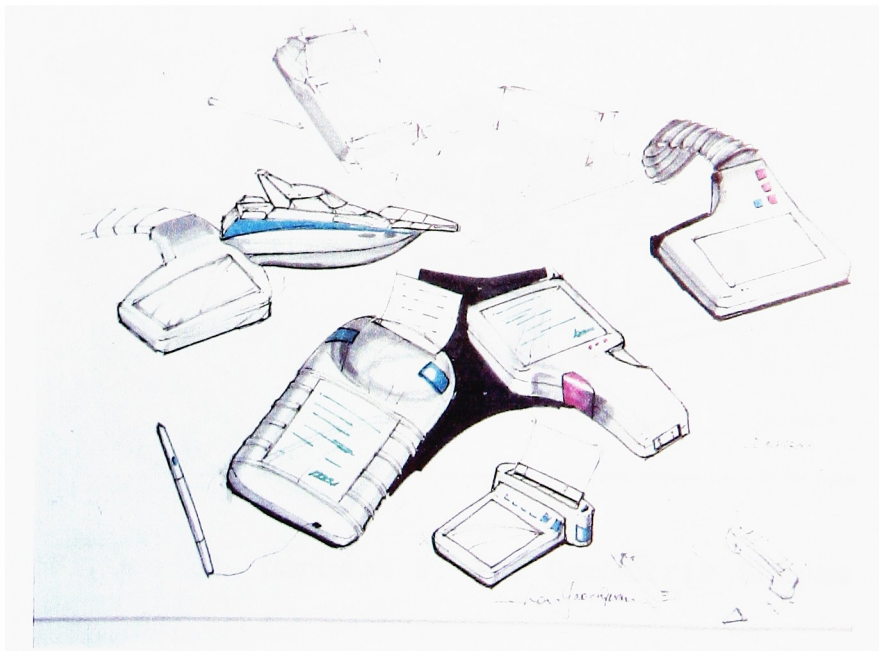


Figure 11. Concept 2: The Calculator Size

In figure 12, I am trying to utilize geometric shapes to reflect different units' functions. For form itself, it really brought good results. But, complex forms present some difficulty for carrying.

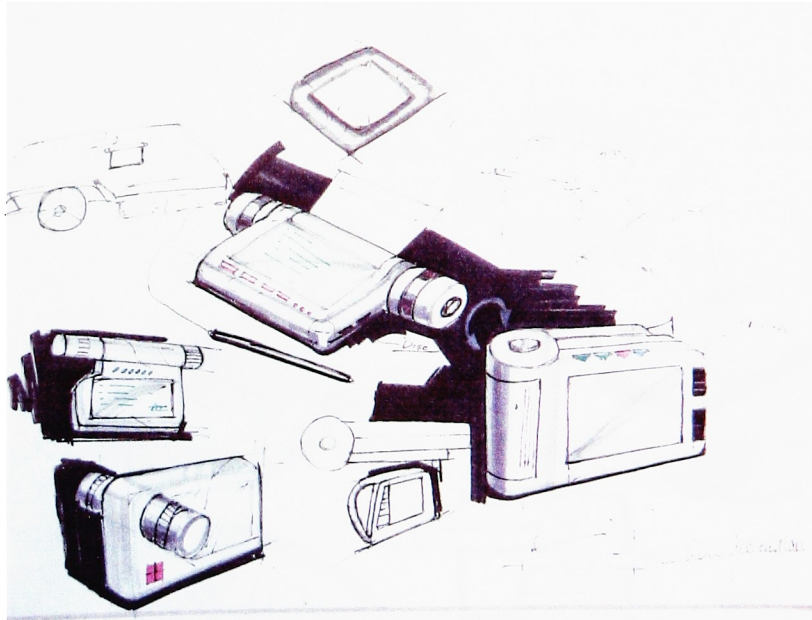


Figure 12. Concept 3: The Geometric Shapes

Figures 13-15 are the pen-based computer carried by using handles. Handles are the typical and easy way for carrying. However, the delivery person usually uses two hands to carry the package, and does not have an extra hand to carry the computer. Thus, carrying by hand is a poor idea for those people.

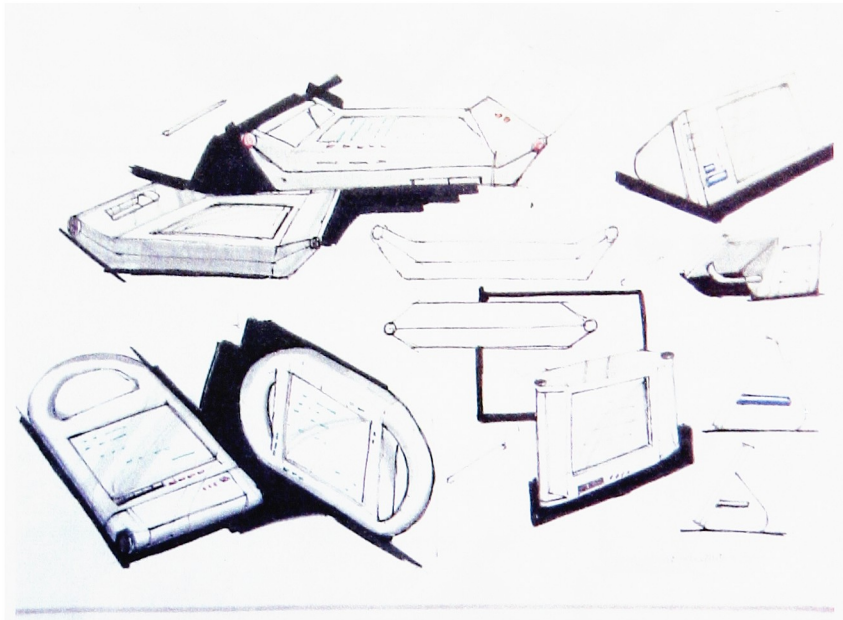


Figure 13. Concept 4: Carrying by Handles





### 7-3 Concepts Development

Two directions are chosen from concepts sketches for development.

#### 7-3.1 Direction A: To Wear on the Wrist

The general idea of direction A is that the system is fixed on the arm for carrying and for protecting from dropping. It also reflects a technology outlook, and builds in a printer and a stylus storage device. The screen is turnable to suit both right-handed and left-handed users. It uses a cover to prevent dust and water coming inside of the computer (See chart 2).

Goals	Possible Solution to Goals			
Carrying	Bag/case	Clip on belt	Pocket	fix on body
Resistance	Seal off	Bag	Cover	
To Avoid Dropping	Texture/Form	Belt/wire	insurance devices	fix on body
Working Surface	Table	Palm	Arm	Body
Suit Right/Left Hand Users	Form	Detach-able	Turnable	
Light-pen storage	Build in	Pocket	Case	
Printer and System	Separate	Build in		

Direction

A

Chart 2. Morphological Matrix- Direction A

The concept which is shown in figure 16 appeared in figure 10. The problem here is that if the screen faces the delivery person in the correct direction, it will be upside down for the customer.

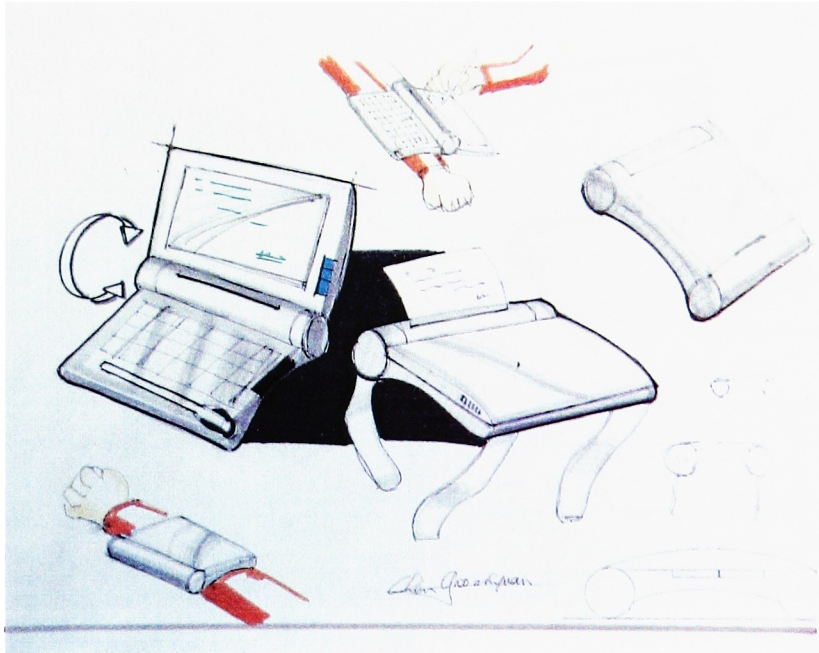


Figure 16. Wearing on the Wrist

A universal joint is used to solve this problem (see figure 17). But this design is complex for users, and too much movement produces more chances for breakage.

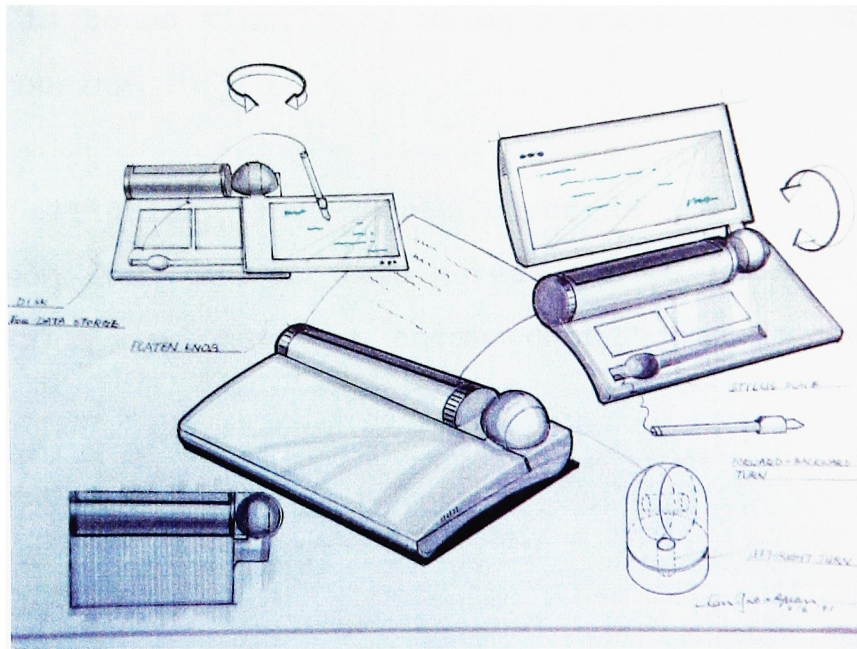


Figure 17. Using a Universal Joint

There is another concept, which is shown in figure 18, for carrying on the arm. This is a space station-like form, and the shape of the base of the computer follows the appearance of the forearm for wearing comfort and stability. It also is bound tightly by using a strap around the palm to avoid dropping.

An elliptical dome-shaped cover is used for protecting the screen from damage. This screen can be turned 180 degrees horizontally in order to accommodate both right-handed and left-handed users.

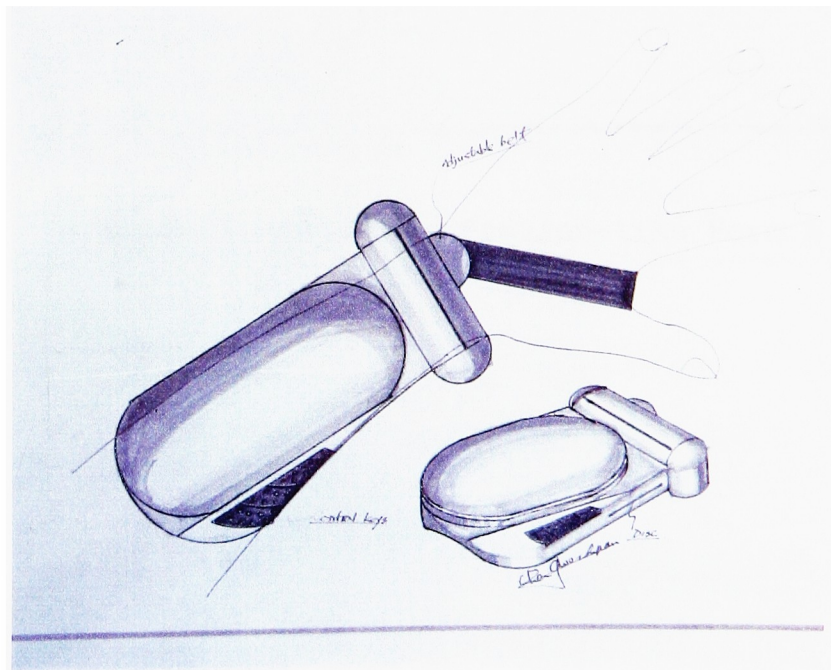


Figure 18. The Space Station-like Form 1



In figure 19 is a variant concept of the one which appeared in figure 20. It is the same idea, but it contains more detail and more complete thoughts. This is the final concept in this direction, and, using this concept I made a mock-up for evaluation.

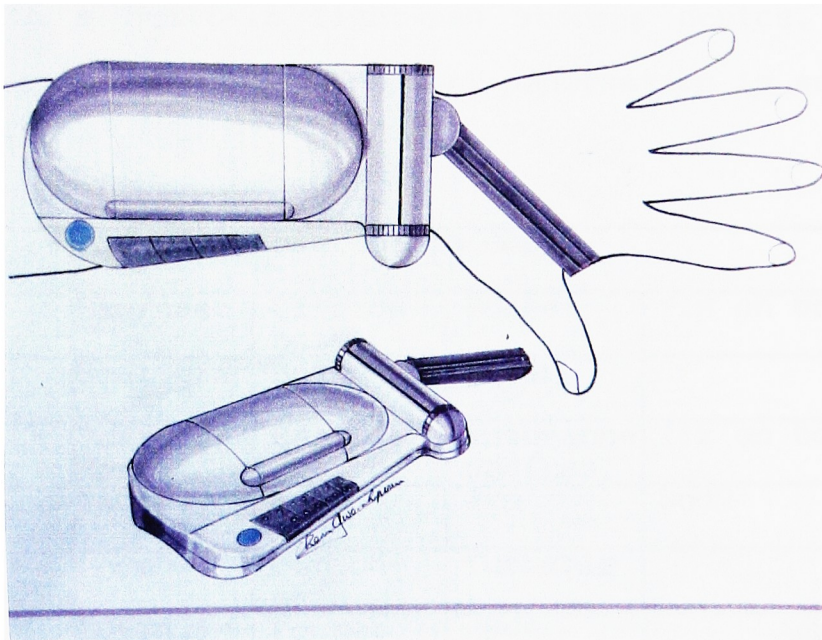


Figure 19. The Space Station-like Form 2

### 7-3.2 Direction B: To clip on the Belt

In direction B, the computer is clipped on the belt for carrying. A form was designed for gripping it firmly and making it comfortable with a view toward fashion. The computer's handle is detachable for both the right-handed and the left-handed user's convenience. This system is also designed with a built-in light-pen storage device, but the printer is separated. Water and dust penetration is sealed off (see chart 3).

Goals	Possible Solution to Goals			
Carrying	Bag/case	Clip on belt	Pocket	fix on body
Resistance	Seal off	Bag	Cover	
To Avoid Dropping	Texture/Form	Belt/wire	insurance devices	fix on body
Working Surface	Table	Palm	Arm	Body
Suit Right/Left Hand Users	Form	Detach-able	Turnable	
Light-pen storage	Build in	Pocket	Case	
Printer and System	Separate	Build in		


Direction 

Chart 3. Morphological Matrix Direction B

In direction B, this system is divided into two units. They are a computer with built-in light-pen and data storage devices, and a carrying case along with a printer.

In the series of sketches shown in figure 20, 21 and 22, I created a form which is based on the shape of the palm.

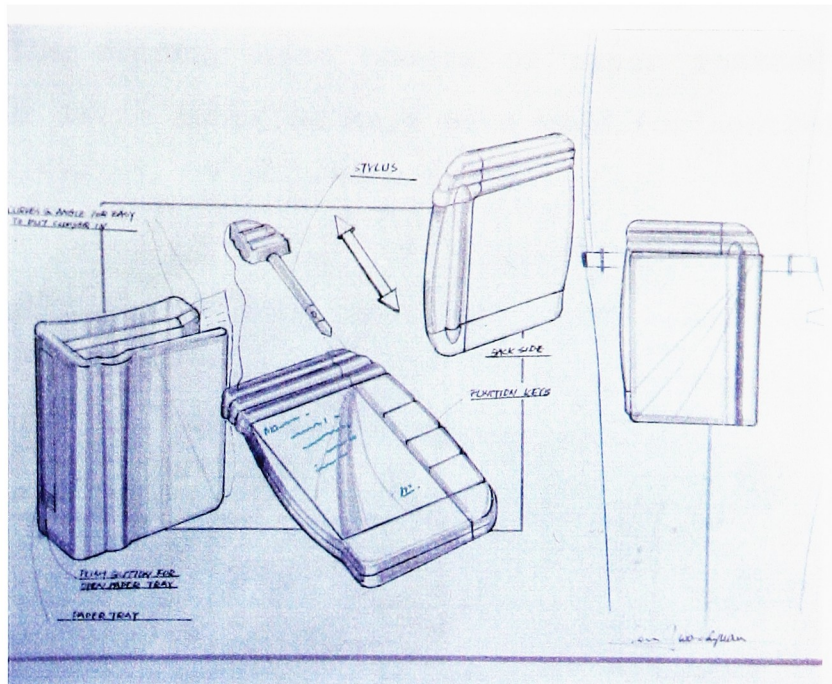


Figure 20. Clipping on the belt 1

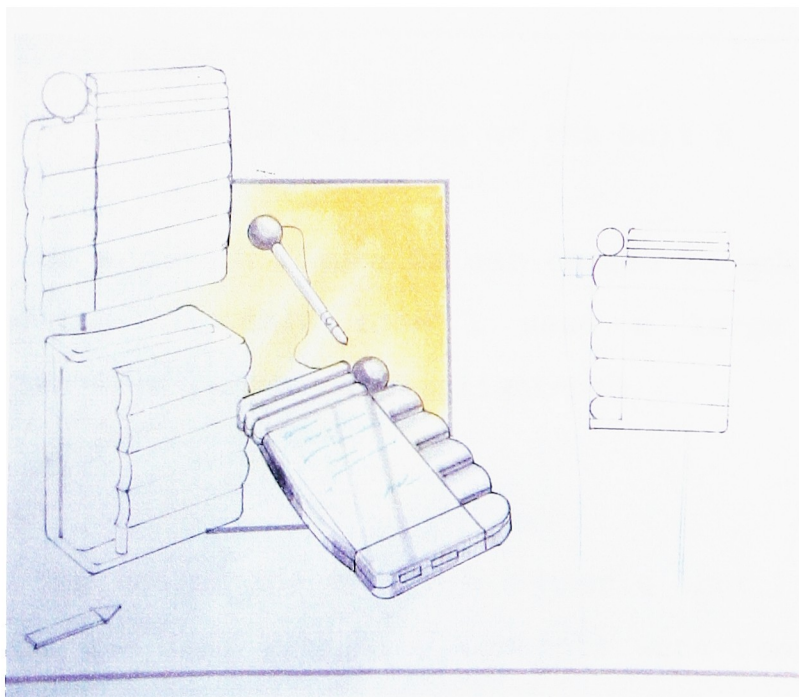


Figure 21. Clipping on the belt 2



Two curves were created for gripping firmly and for comfort. The printer uses sheets of paper instead of paper rolls. Four large function keys were used for control.

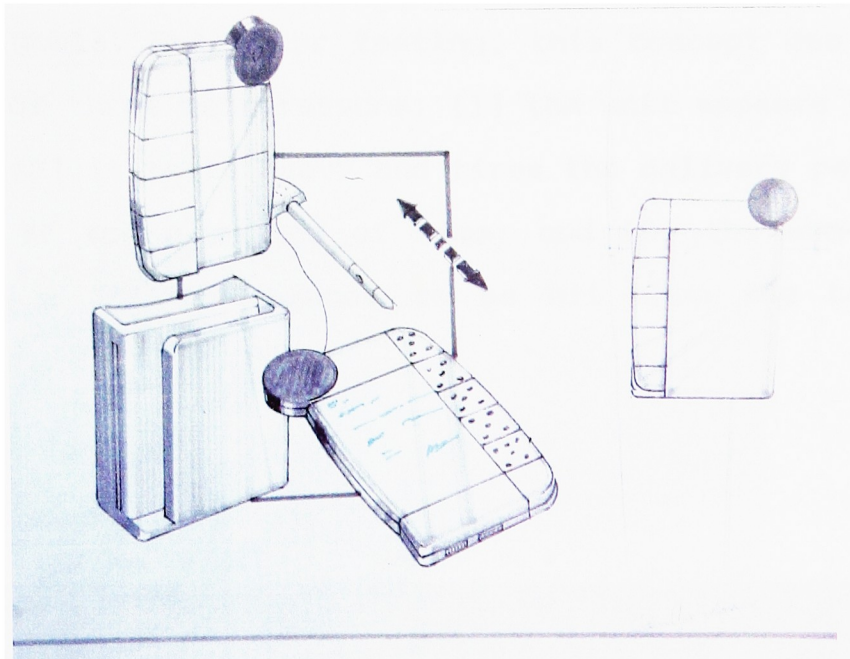


Figure 22. Clipping on the belt 3

The idea shown in figure 22 was chosen to make a mock-up for evaluation. In this idea I used a large circle to emphasize the cord center of the light-pen.

#### 7-4 Mock-up

After evaluating the possible concepts that I created in sketch form, the most promising concepts were converted into three dimensional versions of each direction. I constructed two full-scale mock-ups by using rigid foam. It was possible

to gain an early evaluation of the results based on my design goals.

#### 7-4.1 Mock-up A

This mock-up (figure 23) would achieve most of the defined goals. But after testing, this concept was abandoned because of three main reasons: [1] the unit appears bulky when in use; [2] it feels heavy and tires the delivery person after wearing it for a period of time; and [3] the arm-worn unit produces a lot of chances to be hit when the hand is in motion.

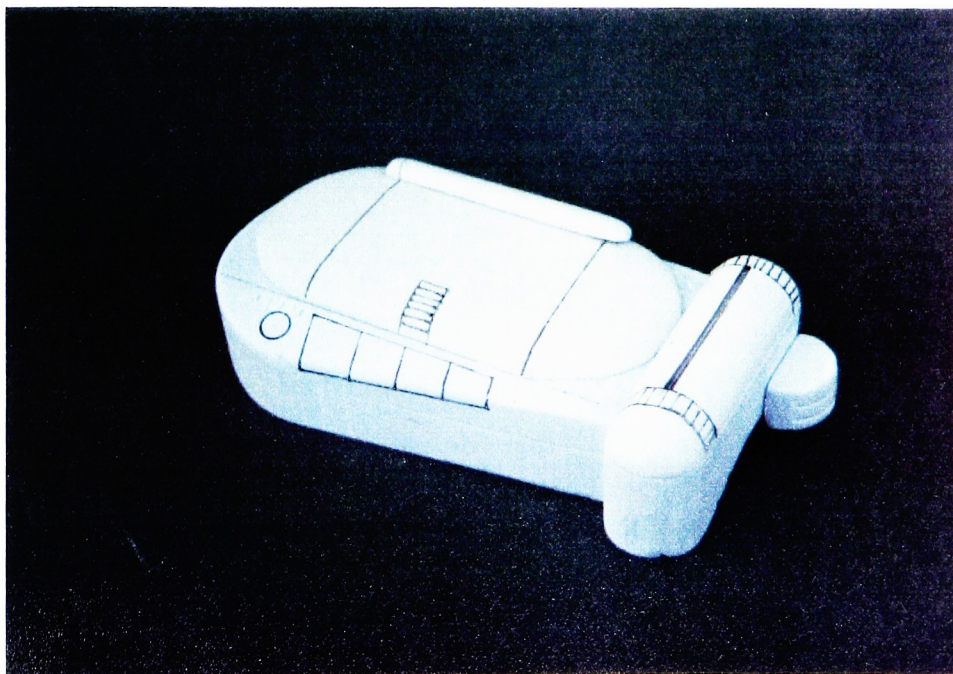


Figure 23. Mock-up A



#### 7-4.2 Mock-up B

This concept (see figure 24) is more promising than concept A, and it matches my design goals. However, there still is a major problem remaining. When the computer is being taken out of or put in the carrying case, the hand has to be bent at an improper angle. This unsatisfactory hand position makes users uncomfortable and creates chances for dropping.

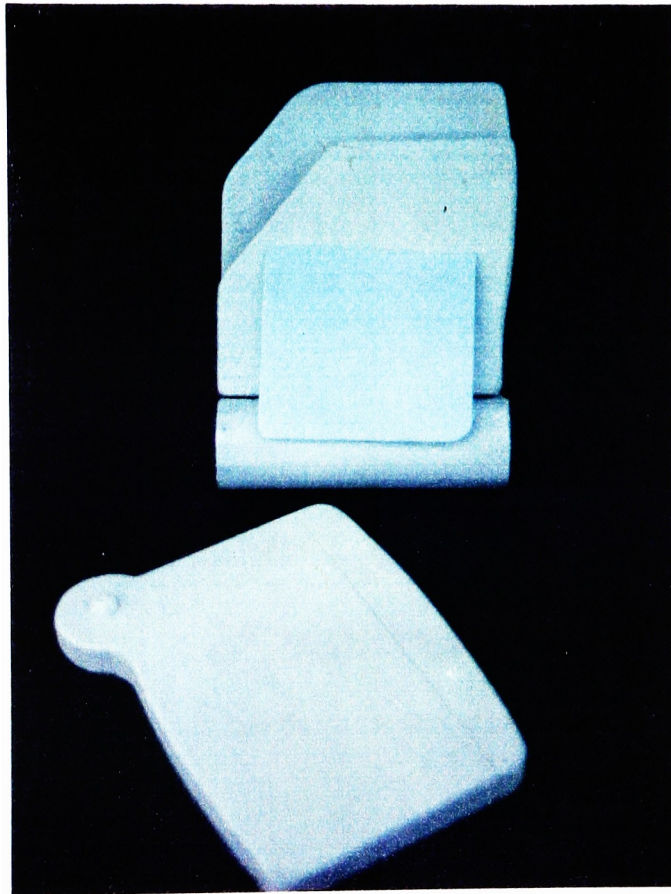


Figure 24. Mock-up B

From these mock up studies, I was able to make an appropriate change in the form of the product. I made two principal changes which involve the way of holding and the direction of the screen. I changed the way of holding from gripping both sides of the computer in a vertical direction to gripping by a handle in the horizontal direction.

### 7-5 Variation and Color Scheme

The series of variations and color schemes shown in figures 25, 26, 27, 28 show some changes of forms, colors and graphics.

The idea shown in figure 28 is the final version of my design, and it was converted to a three dimensional mock-up.

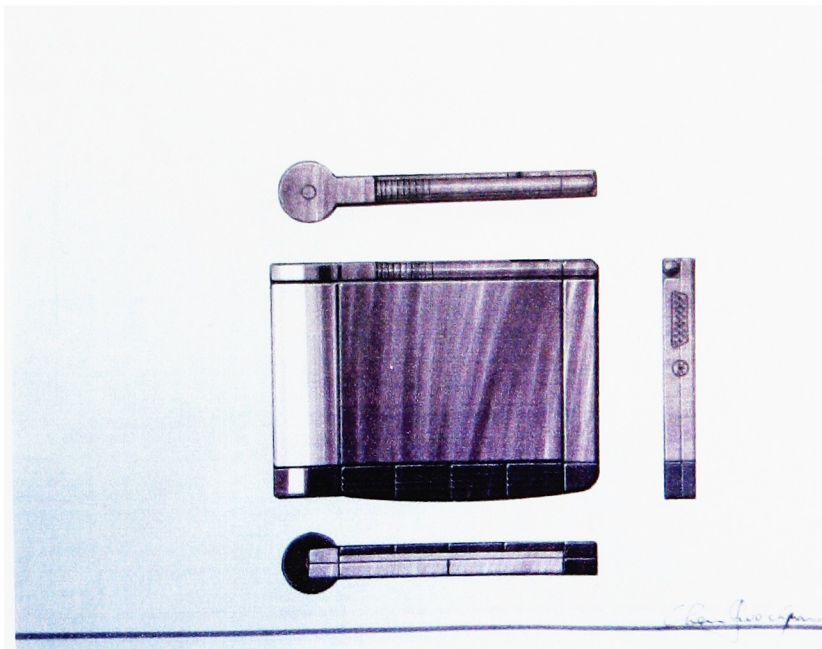


Figure 25. Variation and Color Scheme 1

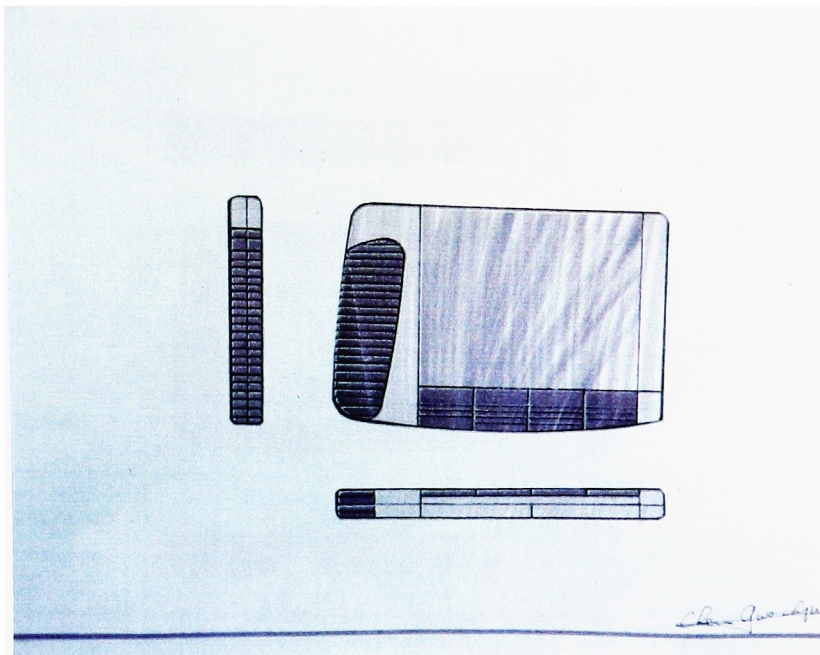


Figure 26. Variation and Color Scheme 2

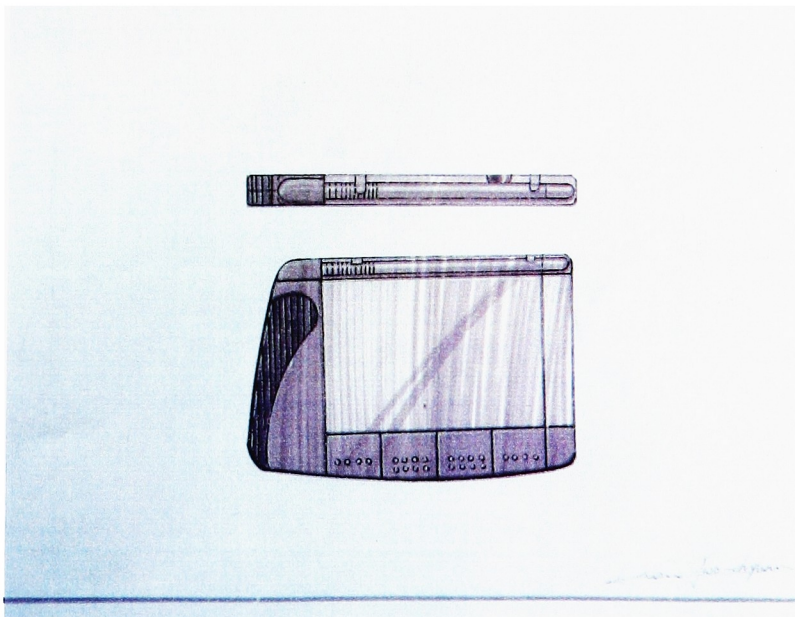


Figure 27. Variation and Color Scheme 3

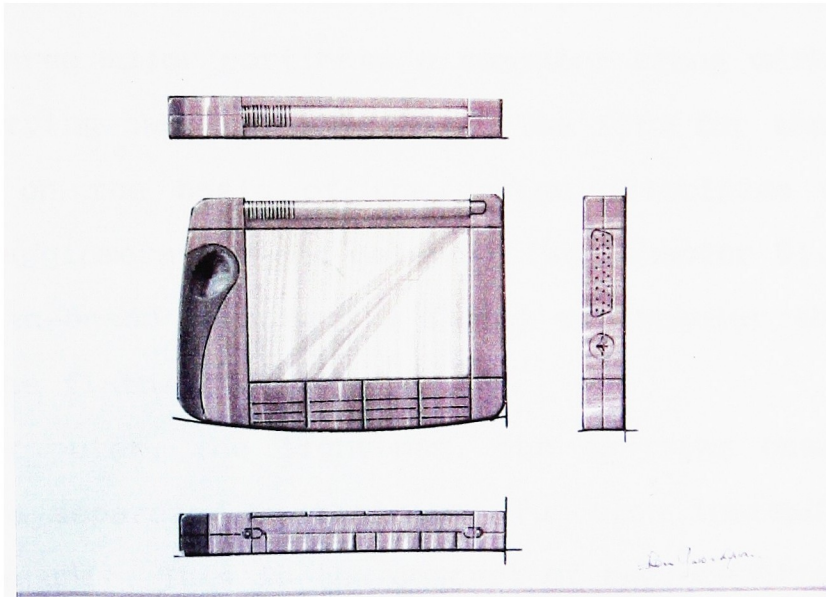


Figure 28. Variation and Color Scheme 4



## 8. THE RESULTS OF DESIGN

The final design of the portable pen-based computer unit includes three major portions: a computer along with a light-pen, a carrying case and a printer. The form for the unit was explored on the basis of the design principles which are flatness, agglomerative and metaphor (see chapter 5).

The pen-based computer is a flat rectangular shape which reflects the flatness principle.

The computer, the light-pen, the carrying case and the printer are separated by their own function instead of being housed as a unit. This is the concept of agglomerative design.

The forms of the printer, the disk drives and the handle allude to the functions of these elements. Metaphor design, as a product language, interprets the practical function of the faceless technology.

The final design result was presented as a full-scale mock-up (see figures 29, 30).





Figure 29. The Full-scale Final Model



Figure 30. The Way of Carrying

## 7-1 The Computer

The function of this pen-based computer offers the proper information to the delivery person, and takes customers' signatures and commands as a record. The user enters data or issues commands through an electronic light pen writing on the screen (see figure 31).

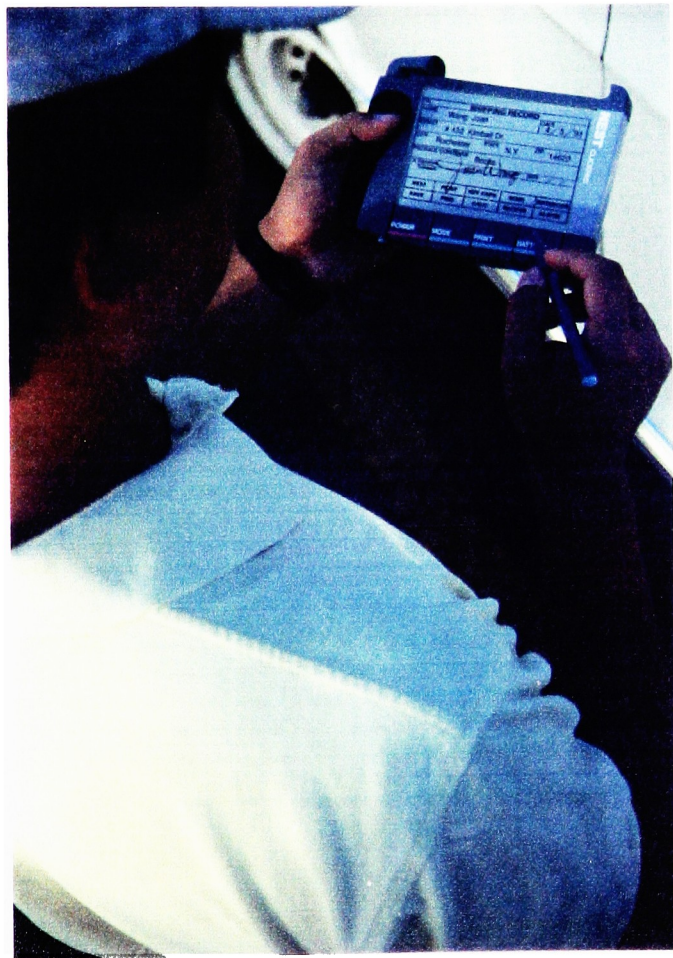


Figure 31. Writing on the Screen by Using the Light-pen



Overall the form is flat and rectangular. The form recalled the first cypher on the new design trends: the flatness. In order to modify the monotonous rectangular shape, I used two large curved surfaces instead of straight ones on the left side and the bottom side. These straight edges and curved edges produce a contrast which provides more interest.

The curved profile adds to the functionality of the unit, too. The curve on the bottom side guides the computer into the carrying case in the correct direction (see figure 32). The one on the left side, which is the handle, is for gripping in a stable and comfortable manner.

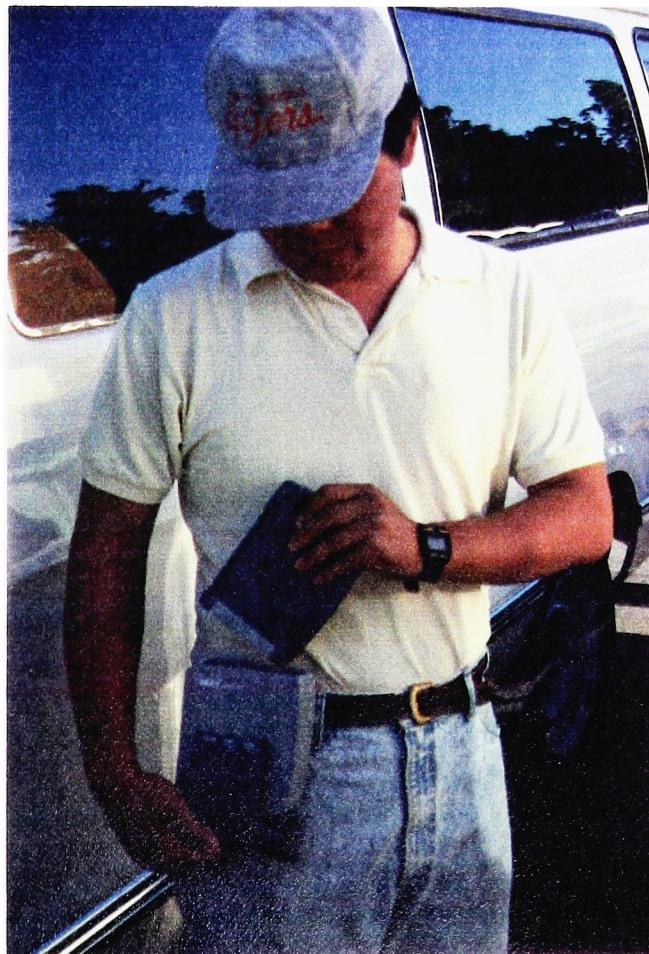


Figure 32. Putting the Computer into the Carrying Case

On the control panel, there are two control keys, a power key and a mode key, and two indicator lights, a printer-in-session light and a battery power remaining light. I used a cylinder form to unify those keys and lights and added pastel colors, which are pastel pink and pastel blue, to present a lively image (see figure 33).



Figure 33. Control Panel

A built in penholder, which is used to put the light pen in, is on the left-top of the computer (see figure 34). It can be turned up or down to assist users in taking out the light-pen easily (see figure 35). There is a device designed to prevent the light-pen from becoming lost. If the pen is not



put in the slot, the penholder won't be turned. Thus, the computer can not be put in the carrying case. This device alerts the user to find out where the light-pen is.

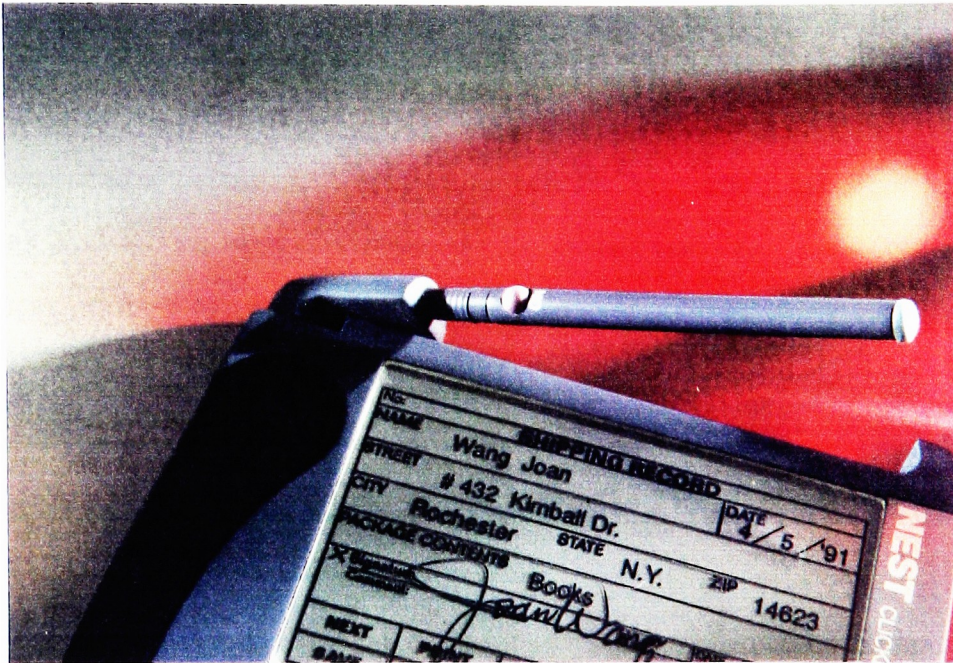


Figure 34. The Light-pen

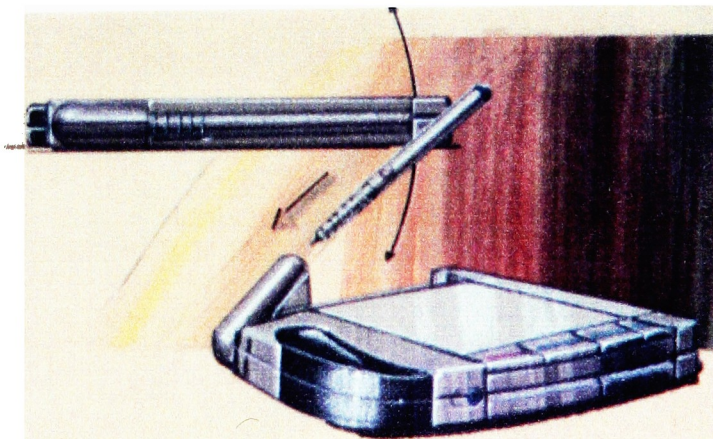


Figure 35. The way to Take the Light-Pen

A remote light-pen has a simple and clear shape to gain a high-tech perception. Round streaks on the upper portion are treated as a language which tells the user to grip here. A sphere-shaped switch is employed here in order to gain a soft touch. The battery cell is at end of the pen, and it is covered with a blue cap.

Two data storage devices are at the bottom of the computer. One is for offering information to the driver and the other for recording the information from customers. These devices use flash solid state disk. I produced an oblique plane as the opening of the cover of the disk driver. It is the design semantic that shows users how to open the disk drive as well (see figures 36, 37).

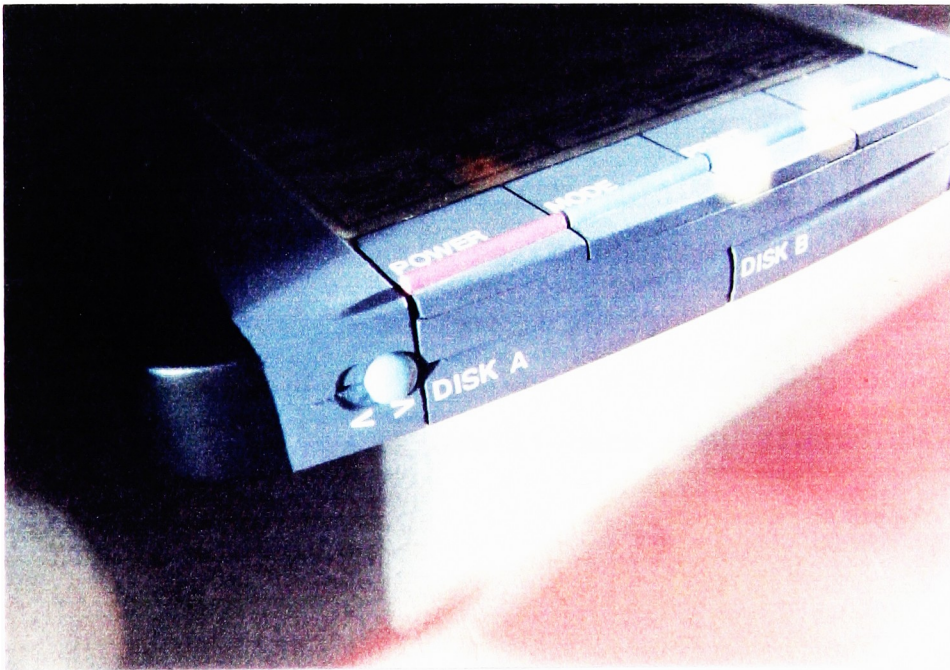


Figure 36. The Disk Drives and the Central Unit Lock



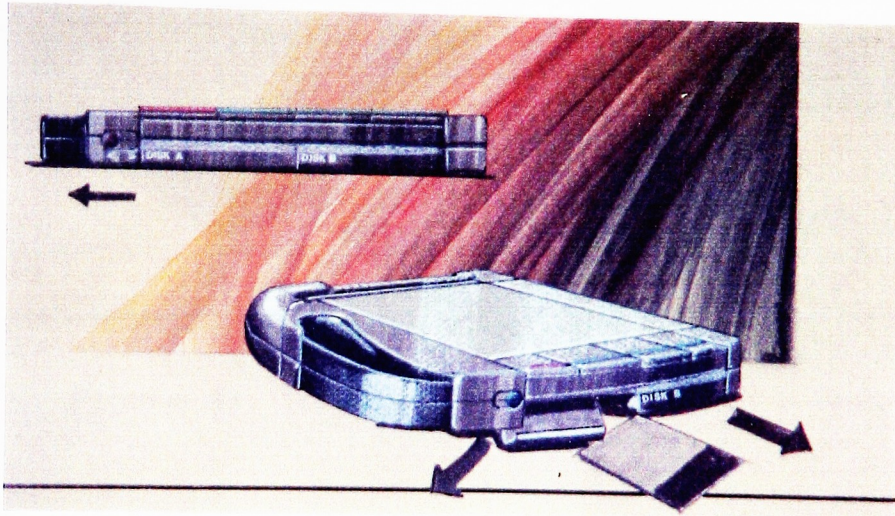


Figure 37. The Way to Use the Disk Drive

For the purpose of accommodating both left-handed and right-handed users, I divided the computer into two units which are the central unit and the outside unit. These two units are linked with a custom-designed connector and fastened by a latch (see figure 36). The user pushes the blue button to the left, and the central unit can be released, then turns this unit upside down and slides it back (see figure 38).

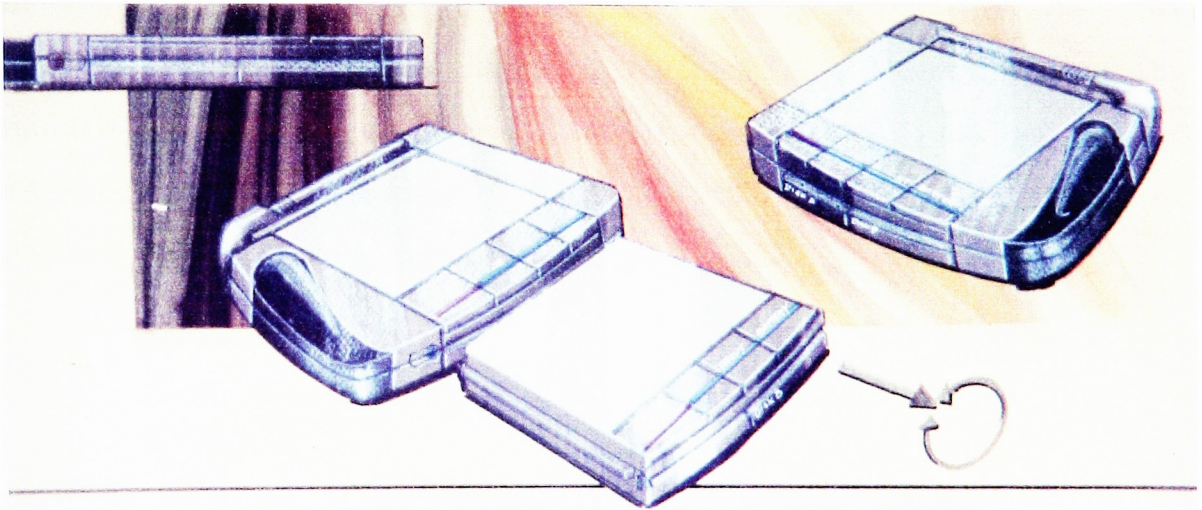


Figure 38. The Way to Turn the Central Unit

The battery package is placed in the right side of the computer. To change the battery, one slides the battery box out, puts in another rechargeable battery and plugs it in (see figure 39).

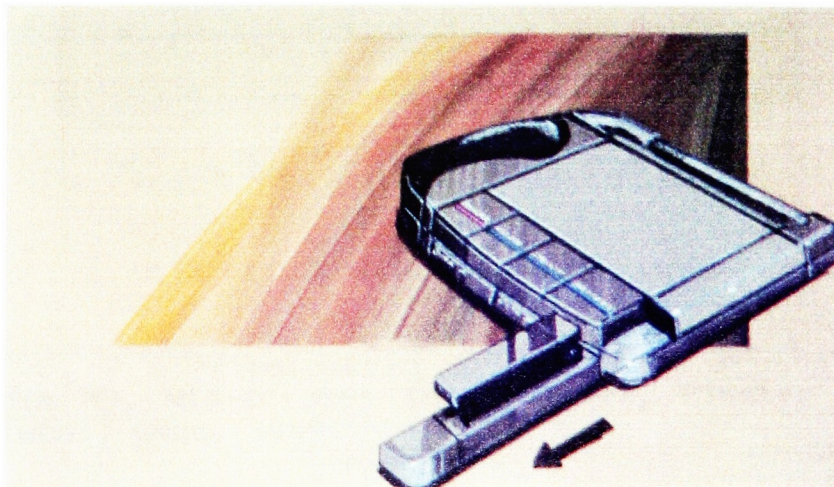


Figure 39. The Battery Package



The form of the handle indicates that this portion is for gripping. The sculptural, curved surface design is for holding, and protects from dropping (see figure 40). The handle of the computer is intended to be made of "Santoprene"<sup>34</sup> (Elastomeric Alloy TPES). This material was chosen for its soft and silk-like touch.

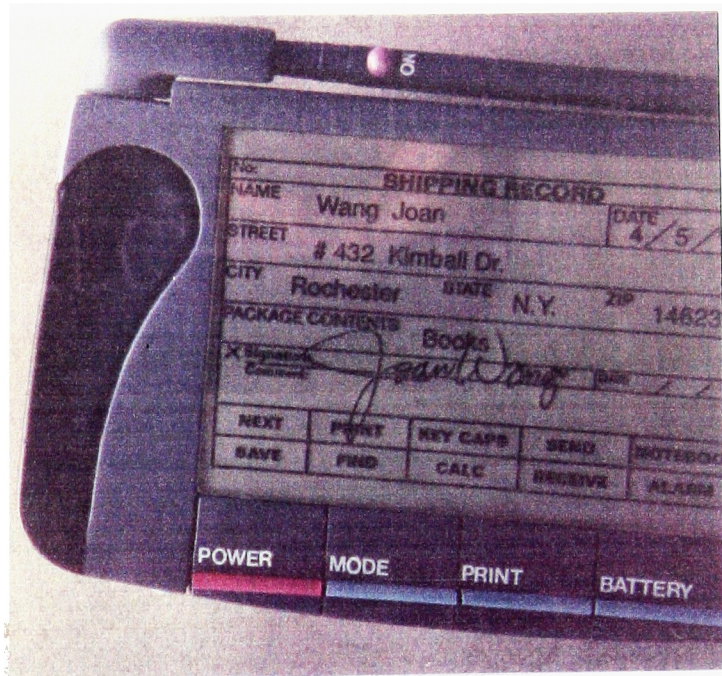


Figure 40. The Sculptural Handle

<sup>34</sup> Rader, C. P., "Elastomeric Alloy TPES", Modern Plastics Encyclopedia 89, Mid-October Issue, p.112, Plastic Catalogue Corp., Bristol, Conn. 1989.



## 8-2 The Carrying Case and The Printer

The carrying case and the printer are joined with a latch. They can be fastened to the belt by a clip. By pushing the button on the lowest part of the case, the case and the printer will be separated (see figure 41).

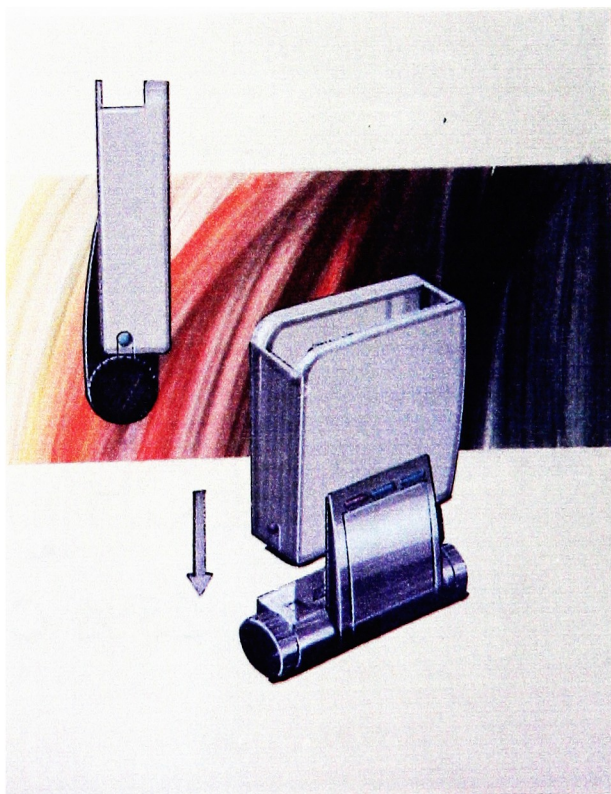


Figure 41. The Carrying Case and the Printer

The form of the printer alludes to a paper going out of a paper roll. It is the metaphor design (see figure 42). There is a cover on the center of the printer. It can be opened in order to load the paper roll. The platen knob is placed on both sides. Knobs are used to adjust the paper.

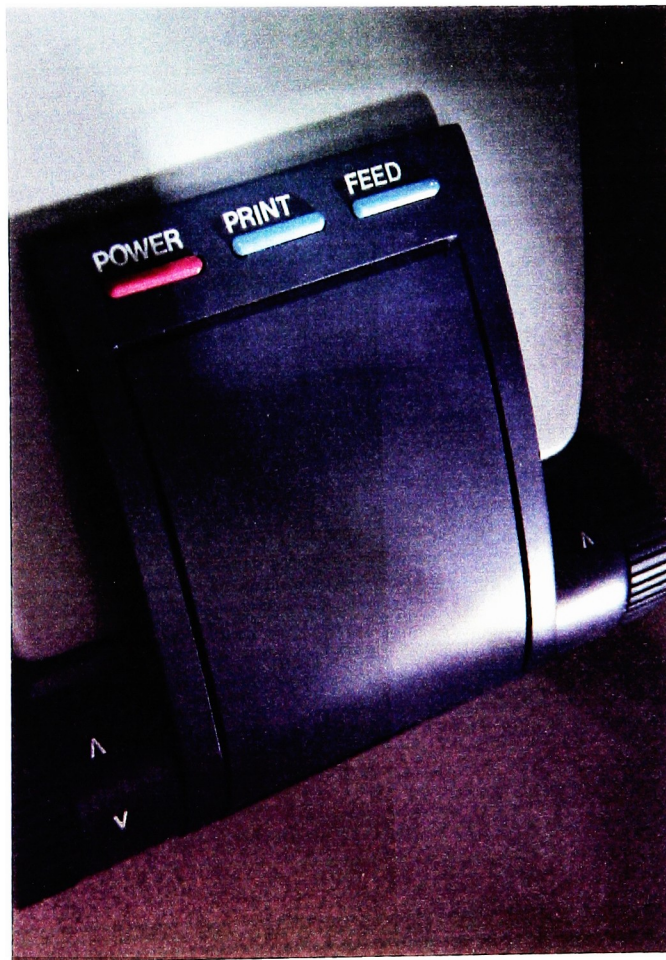


Figure 42. The Printer

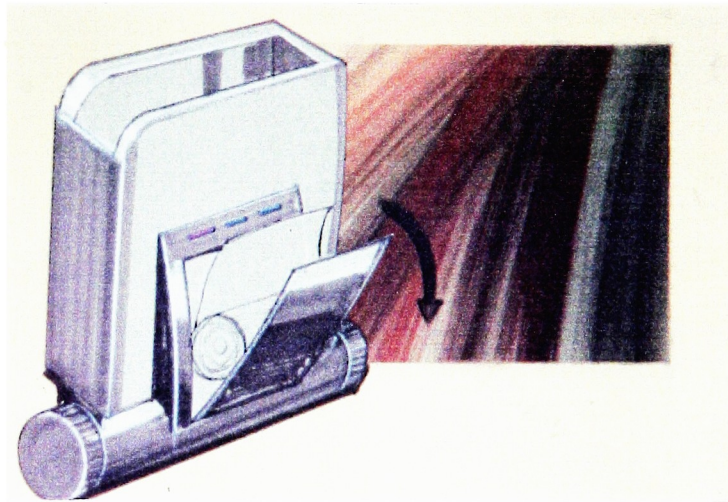


Figure 43. The Way to Load the Paper Roll

Printed paper goes out from the top of the center cover. The delivery person tears off the printed paper and gives it to the customer (see figure 44).





Figure 44. Tearing the Printed Form

### 8-3 Colors

I used three similar, but different, values of gray in the computer. The area of color determines the value, so that a large area is for the light gray and a small one for the dark gray in order to get a good balance visually. Every color area has its open edge for the purpose of getting a chance to "breathe".

I put light gray on the carrying case and dark gray on the printer, not only for visual balance, but also for visual



stability. The deep color looks heavier than the light one. It lowered the visual center of gravity of this unit.

I used the accent colors, which are pastel pink and pastel blue, to unify these three portions into one unit and present a lively image.

#### 8-4 Exhibition

For exhibition, I used a mannequin to present the mock-up. The mannequin was dressed like a delivery person and carried the pen-based computer unit (see figure 45). I used story boards to relate the functions and the feature of my design, as well (see figure 46, 47, 48).



Figure 45. The Exhibition

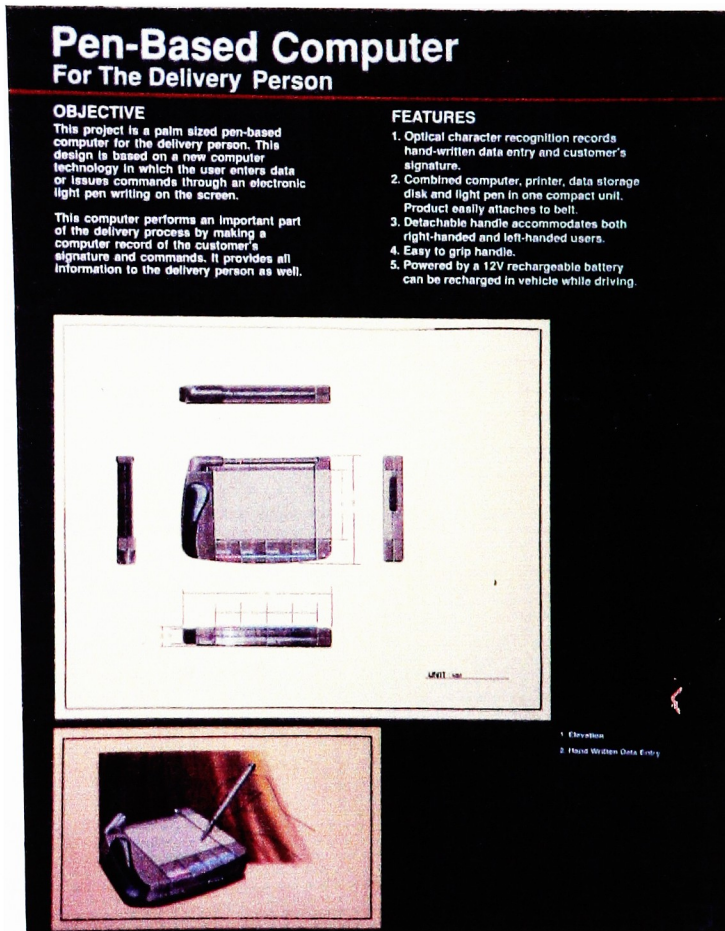


Figure 46. Story Board 1

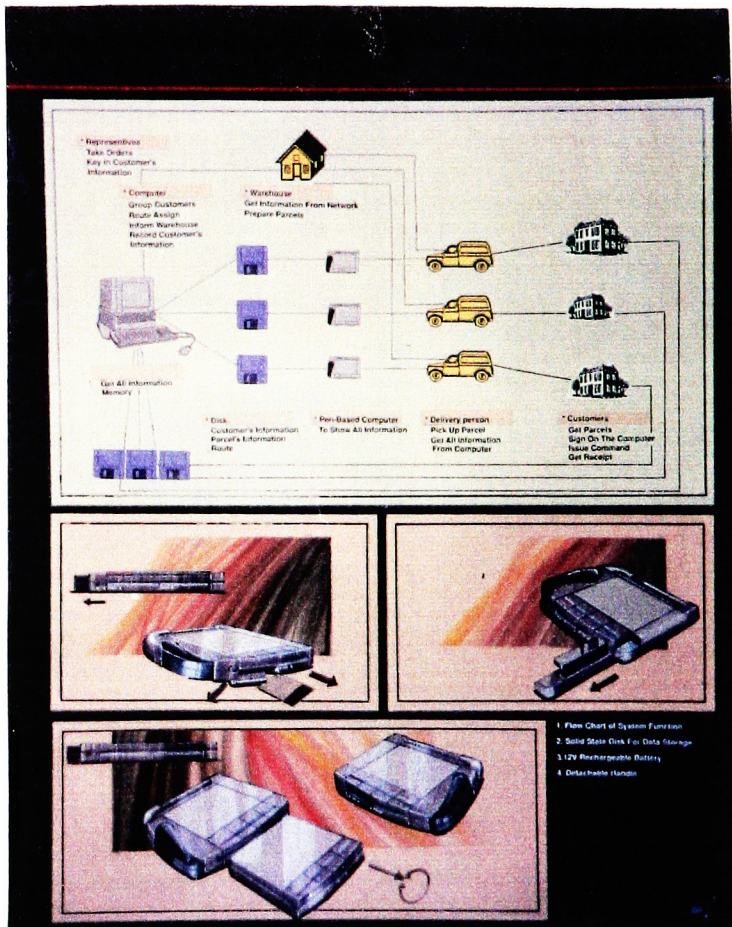


Figure 47. Story Board 2



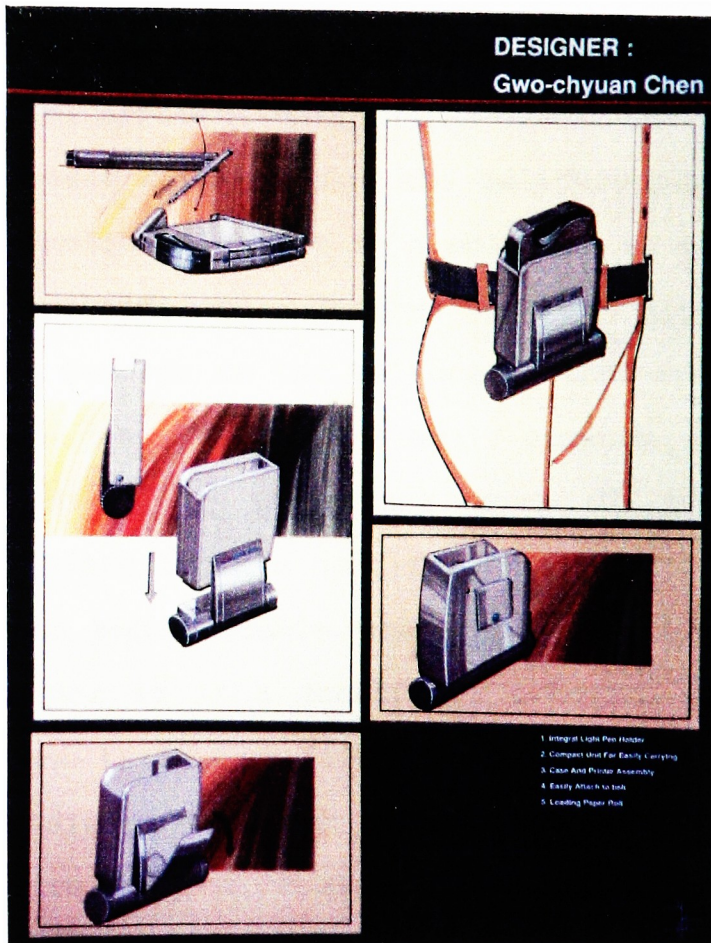


Figure 48. Story Board 3



## 9. CONCLUSION

The pen-based computer unit is a realistic product for the market, and it does add benefits to the traditional keyboard entry computer. However, much of the acceptance relies on useful applications.

The pen-based computer for the delivery person is one of the possible applications. It is a solution to fill the gap of delivery computerization. Whether it is accepted by the delivery trade depends on the balance of cost and benefits. It is expensive, especially for the small company, so far.

On the whole, I feel that most of the goals were accomplished. Since it is a near-future product, I have chosen newly developed and suitable components to present its true sense. But, since it is a conceptual product, it still needs to be tested and to be improved before it is sold in markets.

There is always room for improvement. It may be achieved by the development of microelectronic technology, new needs, and new insights.

Two major weaknesses need to be improved. The user needs to rest his hand when writing on the screen. Sometimes when writing without any hand rest people write as if they were drunk. In this design there is not a designated place to rest the hand. In order to write on the screen, the arm should be suspended or put on the control panel; both of them reduce writing efficiency and accuracy.

Normally, there are two ways to solve this weakness without a dramatic change of the shape. The easiest way is to design the document format that allows for the signature area to be on the top of the screen. Thus, the rest of the screen can be a hand rest. The other method is to change the screen direction from horizontal to vertical. Thereby, users gain a larger area to put their hands on.

Due to the fact that the pen-based computer unit is designed to be compact for ease in carrying, there is not much area to put one's hand on it. In future development, a folding device might be the design solution.

The top-opening case prevents dropping of its contents; however, it is easy to accumulate dust and water, which leads to defects- especially when there is a sudden rainstorm. How to avoid accumulating dust and water, and how to clean the inside of the case are the major concerns of the top opening carrying case.

The accomplishment of my thesis, The Pen-based Computer for The Delivery Person, has allowed me to explore design planning, design methodology and design semantics, as well as product design. The experiences that I gained from the thesis project design will assist me in becoming successful in my future design career.

## BIBLIOGRAPHY

- Cooper, Steve, "A Rugged Alternative to Computer Disks", Automation, pp.33-34, April, 1990.
- Crawford, C. Merle, New Products Management, second edition, Irwin, Homewood, IL, 1987.
- Dormer, Peter, The Meanings of Modern Design, Thames and Hudson, New York, NY, 1990.
- Durbeck, Robert C. and Sherr, Sol, Output Hardcopy Devices, Academic Press, Boston, 1988.
- Free, John, "Electronics Newsfront", Popular Science, pp.37, Jun. 1991.
- Gros, Jochen, "Small but Sophisticated", Design Now Industry or Art, pp.265-299, Prestel, Munich, 1989.
- Marosi, I. and Kovacs, E., "Developing A General Purpose Optical Character Recognition System", Imaging Workstations and Document Input Systems, SPIE Vol. 1074, pp.179-182, 1989.
- Pheasant, Stephen, Bodyspace, Taylor & Francis, London, 1986.
- Sanders, Mark s. and McCormick, Ernest J. Human Factors in Engineering and Design, sixth edition, McGraw-Hill, New York, 1987.
- Sherr, Sol, Input Device, Academic Press, Boston, 1988.
- Urban, Glen L. and Hauser, John R., Design and Marketing of New Product, Prentice-Hall, Englewood Cliffs, NJ, 1980.
- Yankee, Herbert W., Manufacturing Processes, Prentice-Hall, Englewood Cliffs, NJ, 1979.
- Modern Plastics Encyclopedia 89, Mid-October Issue, Plastics Catalogue Corp., Bristol, Conn., 1989.